Four-Dimensional Weather Functional Requirements for NextGen Air Traffic Management

JPDO Weather Functional Requirements Study Team

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EXECUTIVE SUMMARY

The Next Generation Air Transportation System (NextGen) is focusing on a new direction in aviation weather-information capabilities to help stakeholders at all levels make better decisions during weather situations. Safe and efficient NextGen operations will be dependent on enhanced weather capabilities based on three major tenets:

- A common picture of the weather for all transportation decisionmakers and aviations system users
- Weather integrated directly into sophisticated decision-support capabilities to assist decisionmakers
- Utilization of Internet-like information dissemination to realize flexible and cost-efficient access to all necessary weather information.

Air Traffic Management (ATM) personnel, aviation industry representatives, pilots, and weather experts studying the NextGen paradigm have determined that a network-enabled, four-dimensional weather data cube (4-D Wx Data Cube) is the best choice to ensure that accurate weather information is integrated into NextGen operational decisionmaking. A subset of this 4-D Wx Data Cube, known as the 4-D Wx Single Authoritative Source (4-D Wx SAS), provides seamless, consistent weather information for ATM decisions. The 4-D Wx SAS facilitates the integration of weather information directly into operational decision-support tools. This initial report examines the 4-D Wx SAS functional and performance requirements to support ATM.

In June 2007, the Joint Planning and Development Office (JPDO) Senior Policy Committee (SPC) approved a request for agency resources to form a JPDO Weather Working Group-sponsored study team to perform a functional requirements analysis. Terms of Reference (TOR) were provided at the kickoff meeting on July 30, 2007, for the JPDO Weather Functional Requirements Study Team to address the following:

- Identify and document in greater detail NextGen aviation transportation system weather information functional capability requirements (delivered through a 4-D cube concept) as envisioned in the NextGen Concept of Operations (ConOps), including data attributes (e.g., resolution [spatial and temporal], data latency, refresh rate, reliability, integrity, and information content).
- Identify existing agency aviation transportation system weather information capabilities, systems, architecture, and future weather information system plans and requirements.
- Analyze if and how aviation transportation system weather information capabilities, systems, and architecture might be combined to achieve NextGen in a more operationally effective and efficient manner.
- Identify whether any changes might be necessary in government and/or civil systems and planning to take advantage of possibilities to combine functionality.
- Develop and document cost, schedule, and performance attributes at the task level for the 4-D weather cube. If possible, assign agency lead status for each task item.

The JPDO requested that subject matter experts (SME) representing government stakeholders from the Federal Aviation Administration (FAA), the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DOD) comprise the study team. The JPDO considered it important to task those who clearly understood the NextGen concepts and paradigm, but whose primary responsibility was not NextGen-related. The SME expertise included meteorologists, system engineers, and one cost/budget analyst. One study team member had air traffic control experience, and several members were general aviation pilots.

This report describes how the study team addressed the sizable and formidable tasks levied on it and the results of its efforts. One key study team accomplishment was the 4-D Wx SAS definition, which was developed in conjunction with the JPDO Weather Policy Study Team. The 4-D Wx SAS represents the machine-readable, network-enabled, geo- and time-referenced weather information available via network-enabled communications, and has the following characteristics:

- Includes current observations, interpolated current conditions, and predictions of future conditions
- Supports probabilistic decision aids
- Provides a seamless, consistent common weather picture designed for integration into operational decisions and available to all ATM decisionmakers.

The study team's primary task was to provide the necessary functional and limited performance NextGen weather requirements for the 4-D Wx SAS to support NextGen operations. For JPDO agencies to plan and implement NextGen, a functional analysis to the lowest level is essential, as is the development of the associated functional and performance requirements. The team performed a weather functional analysis in accordance with Section 4.4 (Functional Analysis) of the FAA Systems Engineering Manual (SEM), in which government and industry best practices were adopted.

Functional analysis determines the activities that must be performed to achieve a stakeholder's need. It leads to a complete set of requirements that satisfies that need and improves integration, discourages predefined solutions, and enables the incorporation of new and innovative designs and solutions. For this task, the study team extracted operational needs from the NextGen ConOps v2.0 and then decomposed them until sufficient detail existed to determine the high-level weather functions. These high-level functions were iteratively decomposed to determine all required NextGen weather functions. The team translated the resultant functions into limited functional and performance requirements.

The study team performed a validation of user weather needs (survey, interviews, forums, and literature search) to add integrity to the weather functions and 4-D Wx SAS data content. Although some representation of valid user needs emerged, overall user response was insufficient, and additional follow-up is required.

The team was tasked to develop and document cost, schedule, and performance attributes at the task level for the 4-D Wx SAS. SMEs, using two comparables for the development and

implementation of the 4-D Wx SAS, estimated the rough order of magnitude (ROM) costs. The National Weather Service's (NWS) National Centers for Environmental Prediction (NCEP) prepared the estimate for the development of the capability to create the weather information in the 4-D Wx SAS and the operational cost associated with this capability. NWS developed this cost estimate using today's modeling development and system operations to estimate the cost of meeting the 4-D Wx SAS functional and performance requirements detailed in Section 4. The estimated costs to implement the 4-D Wx SAS infrastructure and associated operations were based on the cost to develop and operate the Aviation Weather Center's Aviation Digital Data Service.

The ROM for the development of the capability to create the data for the 4-D Wx SAS (the integrated and consistent observation, analysis, and forecast and the probability data set) was $30 million annually, with 93 percent for implementation and operations and 7 percent for development of the capability. The cost to implement and operate the 4-D Wx SAS infrastructure was estimated at $11.5 million annually, with the cost to format data and store it within the 4-D Wx SAS estimated at $4 million annually. The final ROM for the 4-D Wx SAS is an average of $45.5 million per year.

The JPDO must finalize the draft functional requirements and develop the remaining performance requirements for the 4-D Wx Cube (outside the 4-D Wx SAS). The study team strongly recommends a JPDO-sponsored follow-on initiative to complete the NextGen 4-D Wx Cube functional and performance requirements by leveraging the work of this Functional Requirements Study Team. After all performance requirements have been developed, modeling and simulation activities must be performed with the participation of a representative set of NextGen decisionmakers to refine the initial performance requirements into a complete, validated set of NextGen weather requirements.

This particular release, version 0.1, will be reviewed by the JPDO and the other government agencies deemed most involved in the future development of the 4-D Wx Cube and the 4-D Wx SAS. Version 1.0 will be released after JPDO and agency comments have been evaluated and incorporated as applicable.

1 INTRODUCTION

A Next Generation Air Transportation System (NextGen) key capability—*assimilating weather information directly into decisionmaking*—will dramatically change the way National Airspace System (NAS) decisionmakers use weather information. The NextGen Joint Planning and Development Office (JPDO) has woven this concept into its working documents: the NextGen Concept of Operations (ConOps) v2.0, the initial Integrated Work Plan, the Enterprise Architecture (EA) v2.0, and the Weather ConOps v1.0. The JPDO will refine and update these conceptual and working documents as details become more concise and better defined.

NextGen clearly requires a change in the way weather is collected, analyzed, predicted, tailored, and integrated into aviation decisionmaking. Although the recent advances in meteorology have been astounding, today's weather information is designed for today's requirements. In the NextGen era, "the primary role of weather information is to enable the identification of optimal trajectories that meet the safety, comfort, schedule, efficiency, and environmental impact requirements of the user and the system."[1] The character of weather information today falls short. It has neither the temporal nor spatial resolution required, nor is it updated frequently enough, and it contains inconsistencies (e.g., multiple different convective forecasts). Today's picture of current weather lacks useful quality estimates of weather between sensors for hazards such as icing and turbulence. The perfect weather forecast is still decades away, and today's forecasts do not contain reliable and valuable estimates of weather possibilities (i.e., probabilities) that exist at the time the forecast is made. Also, current weather information is usually not designed to fit the decisionmaker's problem nor would it fit the sophisticated decisionmaker tools envisioned for NextGen. The nature of aviation weather information must change; however, acknowledging that today's information is not good enough for NextGen is quite different from specifying what is. The functional requirements team was tasked to do just that. A group of subject matter experts (SME) set out to provide the initial set of weather information requirements needed for achieving successful NextGen operations.

Air Traffic Management (ATM) personnel, aviation industry representatives, pilots, and weather experts studying the NextGen paradigm have determined that a network-enabled, four-dimensional weather data cube (4-D Wx Data Cube) is the best choice to ensure that accurate weather information is integrated into NextGen operational decisionmaking. A subset of this 4-D Wx Data Cube, known as the 4-D Wx Single Authoritative Source (4-D Wx SAS), provides seamless, consistent weather information for ATM decisions. The 4-D Wx SAS facilitates the integration of weather information directly into operational decision support tools (DST). This initial report examines the 4-D Wx SAS functional and performance requirements to support ATM.

The JPDO, and especially the JPDO Weather Working Group, has presented and discussed the NextGen 4-D Wx Data Cube paradigm at various outreach activities. A common response from NAS users is the need for more detail on the 4-D Wx Data Cube: what exactly it is, how it will be built, and how it will be governed. Government agency planners and agency leaders have offered a similar response, as they require more specific details in order to begin the task of funding and building this cube.

1 NextGen Concept of Operations, p. 5-4.

In June 2007, the JPDO Senior Policy Committee (SPC) approved a request for agency resources to form a JPDO Weather Working Group-sponsored study team to perform a functional requirements analysis to answer some of these questions. The Weather Working Group outlined the study team's task in the Terms of Reference (TOR) at the kickoff meeting on July 30, 2007.

SMEs from multiple government agencies, specifically the Federal Aviation Administration (FAA), the National Weather Service (NWS), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DOD), were solicited to participate on the study team. The study team tapped additional expertise from private industry and other NAS users. The weather and engineering SMEs working on this study team developed the initial set of functions from the JPDO ConOps documents and then translated the functions into functional and limited performance requirements. These requirements have had limited NAS user validation because of minimal involvement from operational users. The JPDO must develop the rest of the functional and performance requirements that define the 4-D Wx Cube [outside of the 4-D Wx SAS]. After all the NextGen weather functional and performance requirements have been developed, the JPDO must validate these 4-D Wx Data Cube and the 4-D Wx SAS requirements. NextGen users and service providers must participate in this validation and any associated requirements refinement. After the requirements are validated, they must be allocated to the appropriate agency.

This study team document describes the efforts the team expended on a sizable and formidable portion of the tasks levied on it (described in the TOR) and documents the results of the completed activities, including some team initiated tasks. Following are the specific tasks:

- Identify and document NextGen weather information functional requirements (delivered through the 4-D cube concept) as envisioned in the NextGen ConOps
- Identify SME-developed initial performance requirements
  - Spatial and temporal resolution
  - Data latency
  - Data refresh rate
  - Reliability [Availability] (minimum .999)
  - Integrity
  - Information content
- Develop and document cost (SME rough order of magnitude [ROM]), schedule, and performance attributes at the task level for the 4-D Wx SAS
- Determine which requirements can be implemented in the 2012, 2016, and 2020 time horizons
- Enhance NextGen EA by providing the next level of weather functions
- Provide comments for the next update of the NextGen ConOps and additional detail and clarification to the next version of the NextGen Weather ConOps
- Determine which requirements need research and development (R&D) to be implemented and added to the Integrated Work Plan

- Provide a set of functional requirements that agency leads can use to build a cost-benefit analysis and plan their fiscal year 2010 (FY10) budget.

The following tasks addressed in the TOR were not completed by the team due to insufficient time and resources and are therefore not included in this report:

- Identify existing agency aviation weather capability, systems, and architecture (Note: The team identified that the NWS does not yet have a sufficiently mature NextGen-specific EA. The DOD EA is mature enough for evaluation and comparison, but the FAA's weather artifacts are in an entirely different format. The team will complete this task before the final version of this report.)
- Analyze if and how aviation transportation system weather information capability, systems, and architecture may be combined to better achieve NextGen in a more effective and efficient manner. (The team identified that the NWS does not yet have a sufficiently mature NextGen-specific EA. The DOD EA is mature enough for evaluation and comparison, but the FAA's weather artifacts are in a different format. The team recommends that a follow-on team completes this task.)
- Identify whether any changes may be necessary in government and/or civil systems to take advantage of any possibilities to combine functions from multiple systems into fewer systems. (Based on the amount of time it takes to complete a functional analysis and the limited availability of experienced functional analysis resources, it was not possible to investigate civil systems. Moreover, a comprehensive comparison cannot be performed until all the NextGen weather performance requirements are developed and validated.)

1.1 SCOPE

To understand the scope of this effort and the specific focus of this set of functional and performance requirements, some important definitions and concepts must be explained. The set of functional and limited requirements will not make sense unless there is an understanding of the specific concepts and definitions of the 4-D Wx Data Cube and 4-D Wx SAS detailed in Sections 2.2 and 2.3. The specifics of the SME cost estimate constitute the basis of Section 1.1.2. Section 1.1.3 clarifies specific topics considered out-of-scope for the study team.

1.1.1 4-D Wx Data Cube and 4-D Wx SAS Definitions

These definitions were coordinated with the JPDO Weather Policy Study Team, which released its initial report, NextGen Weather Policy Findings and Recommendations v0.1, on October 31, 2007. The following bullets are extracted from that policy paper and help define the scope of this team:

- The NextGen Weather ConOps is based on a shared, four-dimensional (three spatial dimensions plus time) database of weather information (4-D Wx Data Cube).
- The NextGen Weather ConOps posits that at least some portion of this 4-D Wx Data Cube must provide a common weather picture for NAS participants. This common

weather picture for ATM is the 4-D Wx SAS. Figure 1-1 helps to illustrate the differences between the 4-D Wx Data Cube and the 4-D Wx SAS.

- NextGen Weather ConOps explicitly states that the 4-D Wx SAS will not be a single physical source (i.e., it is a conceptually unified source distributed among multiple physical locations and suppliers). Similarly, the 4-D Wx Data Cube will be a distributed, virtual system—not a single physical source.

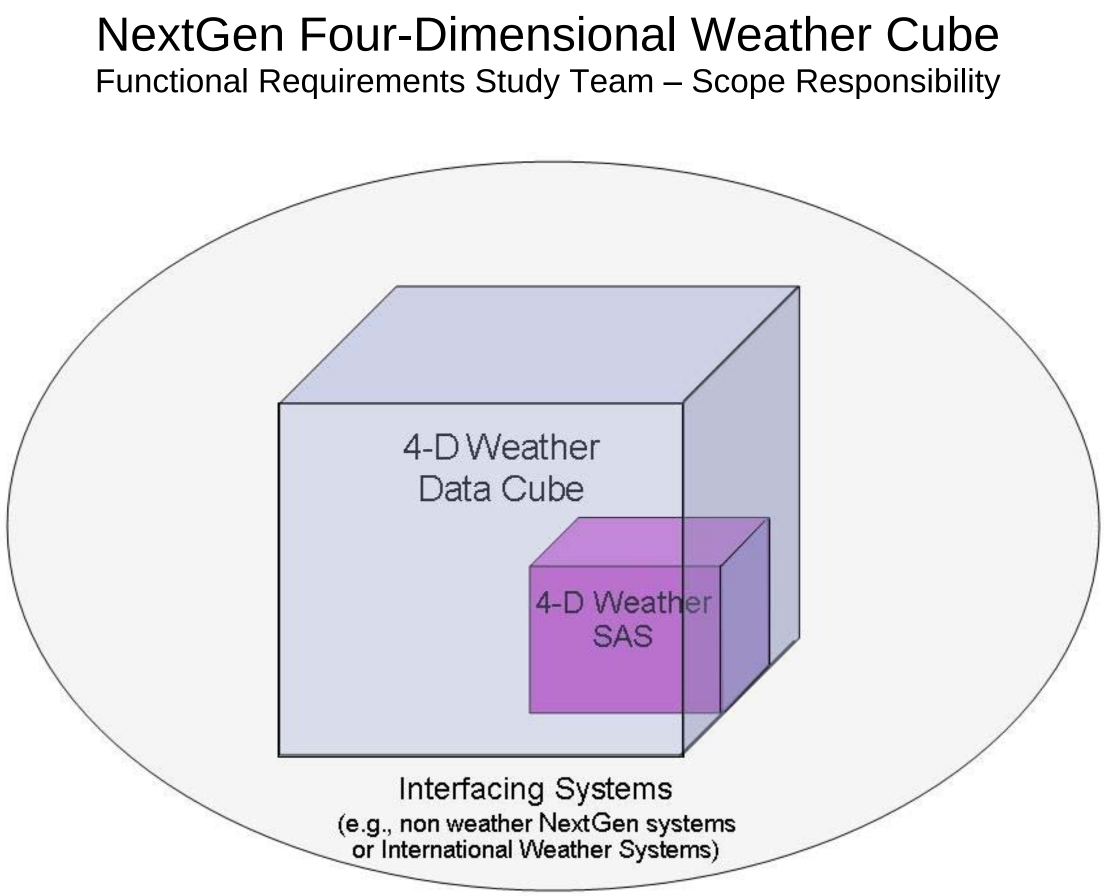
- The 4-D Wx SAS has three characteristics.
  - Includes current observations, interpolated current conditions, and predictions of future conditions
  - Supports probabilistic decision aids
  - Provides a seamless, consistent common weather picture that is available to all ATM decisionmakers for integration into operational decisions.

Although a functional analysis was performed on functions outside of the 4-D Wx SAS to help define the boundary and determine the 4-D Wx SAS data content, the functional requirements included in Section 4 pertain only to the 4-D Wx SAS. The draft functional requirements for the 4-D Wx Data Cube are contained in Appendix M.

Nearly all relevant sources of weather data will be included in the 4-D Wx Data Cube (e.g., surface observations, radar data, satellite data, and forecast model output). However, the federal weather domain authority (the body that defines and implements clear operating rules for determining the data source to be used for a given time and location) will determine which observations will be available in the 4-D Wx SAS and which data from the 4-D Wx Data Cube will be integrated to create the 4-D Wx SAS analysis and forecasts. The NextGen vision has all NAS ATM decisionmakers incorporating this common weather picture into their specific DSTs. For example, various model data solutions will exist in the 4-D Wx Data Cube, but only one integrated forecast of an aviation-specific parameter (and in some cases its associated probability distribution function) will be available in the 4-D Wx SAS. Specific examples of what is not included in the scope of this document are listed in Section 1.1.3.

Figure 1-1. NextGen 4-D Wx Data Cube

This simplified view of the 4-D Wx Data Cube from the NextGen Weather Policy Findings and Recommendations v0.1 illustrates the relationship of the 4-D Wx SAS, the 4-D Wx Data Cube and External Systems that the Functional Requirements Study Team considers largely external to the scope of its work (e.g., operational user systems). The important issues of weather cube domains and data rights are not addressed in this paper or in this diagram. These issues are covered in NextGen Weather Policy Findings and Recommendations v0.1.



1.1.2 SME Cost-Benefit Analysis

As noted in the introduction, the team was asked to provide a SME cost-benefit analysis for JPDO agencies' planning purposes. To develop a reasonable estimate with the limited resources and time available, the team bounded the cost analysis to include the following functions:

- **"Store Weather Information" Function.** This function includes a set of subfunctions directly associated with the 4-D Wx SAS.
  -- Electronic retention of four-dimensional meteorological information—including information such as sensor observations and gridded analyses and forecasts—in an

organized manner such that subsets can be individually retrieved; in today's technology, this feature would likely involve numerous databases
  - Receipt of incoming meteorological information from the NextGen communications subsystem, including ingest and storage functions.

- **"Manage 4-D Weather SAS" Function.** This function includes a set of subfunctions directly associated with managing the weather information in the 4-D Wx SAS.
  - The provision of outgoing meteorological information to the NextGen communications subsystem, including data access, possible formatting (for dissemination), and output queuing. Note that outgoing data could flow in response to scheduled "data pushes" or to external user data requests.
  - The management of the system, administration, and ancillary functions (e.g., hardware and software maintenance, monitoring, security, backup/failover/redundancy).

- **"Generate 4-D Wx SAS Weather Information" Function.** This function creates forecasts for ATM. Estimates are based on available information from comparable existing model and forecast product generation techniques. At this very preliminary phase of the NextGen project (i.e., pre-design functional requirements specification phase), a wide envelope of uncertainty is associated with the resulting cost estimates.

- **"Format Weather Information for Storage" Function.** This function involves formatting data (e.g., the reorganization and representation of information) for storage in compliance with established standards, guidelines, and conventions. At this writing, the evolving set of NextGen-supported weather data formats is undefined. When considered in its totality, the NextGen system will likely support a vast number of weather data formats. However, from a functional requirements perspective, the 4-D Wx SAS needs to support the formatting capability to convert only a relatively small number of fundamental weather data types such as text, grids, and likely several others for storage. Each type can be represented in numerous yet-to-be-determined formats, and support for each format typically entails encoders and decoders that enable the ingest, storage, and extraction of weather information. Numerous factors will influence the ultimate weather data format choices, including the state of accepted standards within the global hydro-meteorological community and interfaces with existing systems.

1.1.3 What Is Not in Scope

To clarify the scope of this paper and the requirements set, a list of what was *not* covered is provided below. Topics requiring a more thorough investigation and analysis may be addressed in later sections specifying recommendations and follow-on activities.

- The "domain authority" process that determines which weather from the 4-D Wx Cube is integrated into the 4-D Wx SAS.

- NextGen policy issues discussed in the policy team paper
  - Policy implications (e.g., data rights) of weather concepts
  - Agency roles and responsibilities for weather
  - Federal agency cost apportionment for weather

- Changes in flight regulations resulting from the NextGen weather concept and the entire NextGen paradigm
- Sensors (hardware) and sensor data (though a subset of sensor data will flow into 4-D Wx SAS, e.g., aviation routine weather reports [METAR]), which are defined in Appendix A)
- Development, maintenance, and operation of atmospheric numerical weather prediction models not specific to aviation
- Communications, including physical hardware and communications software languages and protocols (e.g., Extensible Markup Language [XML])
- User subscription functions
- Long-term data archiving

1.2 RATIONALE

The Functional Requirements Study Team's work will be used to address the needs of the system engineers and agency planners. The system engineers will add these requirements to the EA, Integrated Work Plan, and later versions of NextGen ConOps documents. Agency planners will use the set of requirements developed from the functional analysis work to make budget and manpower decisions, and request appropriations. The study team strongly recommends the conduct of follow-on work to validate the requirements with NAS users and then refine these requirements through modeling and simulation. The study team is confident that the requirements set presented here - developed with both meteorological, system engineering, and limited operational subject matter expertise - will meet the goals specified in Section 1, Introduction.

1.3 DOCUMENT ORGANIZATION

This report begins with an executive summary. Section 1 is an introduction which highlights the document's scope, rationale, and organization. Section 2 highlights the assumptions that the study team used in the functional analysis, 4-D Wx SAS requirements development, and other activities documented in this report. Section 3 discusses the methodology used to collect and present the information, including the subject matter expertise from study team members, the functional analysis and requirements development training, and the software tools used to produce the diagrams. Section 4 highlights the functional and performance requirements for the 4-D Wx SAS. Section 5 documents the initial operating capability (IOC) in 2012, 2016, and for the end state in 2020. Section 6 develops and documents cost (SME ROM), schedule, and performance attributes at the task level for the 4-D Wx SAS. Section 7 discusses the risks and challenges of transitioning toward NextGen weather. Section 8 highlights the methods the team used to validate the findings in the report and examines possible future gaps. Section 9 identifies recommendations and follow-on actions. These nine sections are followed by 13 crucial appendices that include several types of functional diagrams, EA diagrams, a large lexicon, acronyms and abbreviations, validation survey questions with documented user needs, references, study team member biographies, suggested changes in the NextGen Weather ConOps, and to weather-related sections of the entire NextGen ConOps, plus complete background information on the SME ROM. The final appendix details the draft functional requirements for the entire 4-D Wx Data Cube.

2 ASSUMPTIONS

To describe the functional requirements in the midst of a maturing NextGen ConOps, thoughtful assumptions are necessary. The basis of these assumptions comes from information contained within the resource documents identified in Appendix J. Some extraction beyond the content of these reference documents was necessary to further develop or describe concepts required for the analysis.

2.1 ALLOCATION AND ASSIGNMENT OF ORGANIZATIONAL RESPONSIBILITY FOR THE PROVISION OF WEATHER INFORMATION IS NOT A PART OF THIS REPORT

This initial document identifies functional and performance requirements for the 4-D Wx SAS as described in the referenced ConOps documents. It does not provide recommendations for assigning responsibility for funding and supporting the solutions needed to meet the requirements described herein, but leaves this responsibility to the JPDO for direction and the appropriate agencies for action.

2.2 THE 4-D WX DATA CUBE

At the core of the NextGen weather capability is the 4-D Wx Data Cube, which is defined as all unclassified weather information used directly and indirectly for making aviation decisions. It contains all relevant aviation weather information (e.g., observations, automated gridded products, models, climatological data, and human-produced forecasts from public and private sources). The 4-D Wx Data Cube is composed of text products, graphic products, and machine-readable products. It contains proprietary products and those in the public domain, as well as domestic and foreign weather information. The production of the 4-D Wx Data Cube and its utilization by NAS users' applications in an operational manner is the essence of NextGen weather capabilities.

Because the 4-D Wx Data Cube contains *all* relevant aviation weather information from different observation sources, models, algorithms, and providers, it will contain information that occasionally conflicts and will have variable performance attributes, including accuracy, availability, statistical reliability, consistency, refresh rates, and resolution in time and space.

Therefore, a means is needed to arbitrate or *merge* 4-D Wx Data Cube information into a common weather picture upon which stakeholders, especially air traffic managers, can rely.[2] A means is needed to *fuse* multiple weather observations and forecasts into a four-dimensional common weather picture available to all users.[3] An authorized common weather picture is needed to facilitate decisionmaking by a diverse set of stakeholders making coordinated air traffic management decisions using a variety of applications, decision tools, displays, and text products. That common weather picture is the 4-D Wx SAS.

[2] NextGen ConOps v2.0, Section 5.3, Weather Information Services, p. 5-4.
[3] NextGen ConOps v2.0, Section 5.3.3, Weather Information Enterprise Services, p. 5-8.

2.3 THE 4-D WX SAS

At full NextGen implementation, the 4-D Wx SAS for ATM represents the machine-readable, network-enabled, geo- and time-referenced weather information authorized for use by ATM for decisionmaking. The NextGen ConOps defines ATM as “the dynamic, integrated management of air traffic and airspace—safely, economically, and efficiently—through the provision of facilities and seamless services in collaboration with all parties.” This definition of ATM encompasses airspace organization and management; flow and capacity management; and en-route, terminal, and airport air traffic control. The 4-D Wx SAS provides *the* answer to all ATM operations looking at the same weather attribute for a given place and time.

Information contained in the 4-D Wx SAS is located in a virtual database, which means the entire 4-D Wx SAS is not necessarily located on any single system or at any single location. Network-enabled capability makes the physical location of information irrelevant; that it can be found and retrieved quickly and reliably when needed is the important point. Response time for 4-D Wx SAS information requests will meet user-specified time requirements. Refresh rates will differ according to the requirements for each data type. For example, analyses and forecasts of convection will be refreshed more often than those for space weather.

Although the 4-D Wx SAS is the sole source of weather information for ATM functions, other communities of interest in the NAS will have access to its information (as well as to most other network-enabled weather information in the public domain). The only cost to access the 4-D Wx SAS is the minimal communications cost.

The temporal and spatial resolution of the 4-D Wx SAS varies according to geographic region and air traffic management purpose. For airspace in which aircraft are in close proximity and operations are highly active, temporal and spatial resolution will be higher. For less active air traffic operations or for low volumes of traffic, temporal and spatial resolution will be lower. Temporal and spatial resolution over the oceans may not be as high as that over land. Refer to Section 4 for the spatial and temporal requirements for the 4-D Wx SAS.

Information in the 4-D Wx SAS covers United States Flight Information Regions (FIR) from the surface of the Earth up to low Earth orbit (500 kilometers). To cover foreign FIRs, the 4-D Wx SAS contains weather information from foreign sources selected by the domain authority. At a minimum, this includes observation data at international airports and forecasts for terminal area forecast (TAF) elements, information found in significant meteorological information (SIGMET) and related products, weather aloft information, and space weather as provided by international agreement such as those sponsored by the International Civil Aviation Organization (ICAO) through the World Area Forecast System.

Some weather elements in the 4-D Wx SAS may be derived from other weather information within the 4-D Wx SAS. For example, 2-minute wind speeds and 10-minute average runway visual range are not measured directly, but are calculated from 4-D Wx SAS values. Other derived products that represent ATM-relevant weather information will be considered and evaluated for possible inclusion in the 4-D Wx SAS. The motivation for including such phenomenon or event-oriented products is to highlight features that might not be clearly identified or expressed by the fundamental geophysical parameters of the core 4-D Wx SAS.

These derived products are not yet specified, but could include information on frontal positions, jet cores, and other such phenomenon that are not necessarily revealed by the parameter-oriented construct of the 4-D Wx SAS. Also, some information is not specifically in the 4-D Wx SAS, but is calculated in the user's decision-assist tool. For example, density altitude is calculated using temperature, dew point temperature, and altimeter setting from the 4-D Wx SAS along with local altitude. A design decision will determine which derived information will be a part of the 4-D Wx SAS, and which will be calculated outside of it.

Both government and private organizations may contribute to the 4-D Wx SAS. In general, if a private organization supplies information authorized for the 4-D Wx SAS, that information is in the public domain.

The purpose of the 4-D Wx SAS is to provide a standardized source for aviation weather elements (e.g., turbulence and icing) used for making air transportation management decisions. Because the 4-D Wx SAS comes from the 4-D Wx Data Cube, the weather information is integrated (the NextGen ConOps uses the terms "fused" and "merged") to obtain internal consistency before it becomes part of the 4-D Wx SAS. Creating integrated information means that many information sets in the 4-D Wx SAS are unique and may not reflect any one of the Cube sources that were used for merging.

The domain authority is a recommended joint FAA, National Oceanic and Atmospheric Administration (NOAA), and DOD function established to carry out business rules that will identify specific weather information for specific applications. The purpose of the domain authority is to ensure that all decisionmakers who request weather information for a similar location, time, and application receive consistent information. To prevent potentially conflicting weather information from being provided to different decisionmakers, the domain authority defines and implements clear operating rules for determining the data source to be used for a given time and location.

NextGen decision-support systems use a risk-management approach in planning capacity management and flow contingency management options.[4] Probability expresses the likelihood that the decisionmaker will encounter the element being forecast. By using a probability of a consequential weather event, decisionmakers can mitigate the impact of that weather element. A majority of the 4-D Wx SAS weather forecast elements will require probabilistic content designed for the many decisions that depend on them. As a consequence, the 4-D Wx SAS will provide the probability for a variety of weather elements to exist at the same point and time. For example, a probability of light icing will exist at the same time as the probability of severe icing, providing the likelihood of all outcomes. Both of these probabilities are represented in the 4-D Wx SAS because they have different consequences for different decisionmakers.

Observations are not available for most of the NAS or for all times at observation sites. Estimates of conditions between observations, both in time and space, are needed for flight planning and capacity determinations. Different sources of observations are integrated into a single analysis of atmospheric conditions to improve the quality of decisionmaking at each point in the NAS. For example, a mountain pass may have no automated surface-observing systems

[4] NextGen ConOps v2.0, Section 5.3.2, Weather Information Services, p. 5-5.

(ASOS) measuring cloud heights. However, a satellite can determine there is no ceiling over that site with high confidence, or with low confidence when cloud cover is present. Adding a probabilistic component to "present weather" will improve its utility to the decisionmaker in determining the associated weather risks to operations. Consequently, the meteorological values of each parameter (e.g., visibility or convection) at each point of the atmosphere may be characterized not only as a single value, but may contain a probability, or confidence, that the value at that point is correct.

Users will access 4-D Wx SAS weather information primarily through decision support systems, or view it through multi-purpose integrated display systems (in the early years through legacy stand-alone systems). Text and "hard" graphic products still required by the Federal Government or by international agreement (e.g., TAFs, METARs, and Volcanic Ash Graphics) will be formatted from the information in the 4-D Wx SAS, but will not be part of the 4-D Wx SAS.

Air navigation system providers (ANSP) and other NextGen users have DSTs that incorporate weather data to improve human assessment of weather impacts. This allows decisionmakers to optimize their response to weather's potential operational effects (both tactical and strategic) and minimize the level of traffic restrictions. DSTs range from fully automated machine-to-machine decision systems to those that simply aid human decisions. Research and analysis will determine the appropriate functional allocation of tasks among ANSPs, flight operators, and automation. It will also determine when DSTs are necessary to support humans (e.g., identifying conflicts and recommending solutions for pilot approval), and when functions should be completely automated with no human intervention.

Sensor observations in the 4-D Wx SAS are in machine-readable format, not in traditional formats such as today's METAR or aviation selected special weather report (SPECI); these are created outside the 4-D Wx SAS using 4-D Wx SAS information. An observation will not become a part of the 4-D Wx SAS until quality control has been performed.

Alerts, advisories, and warnings are not normally in the 4-D Wx SAS. They are generated by applications outside the 4-D Wx SAS in two ways:

- Information packages containing general alerts, advisories, or warning messages will be created outside the 4-D Wx SAS according to required specifications (e.g., ICAO Annex 3) when forecast or observed weather variables exceed universal system-wide thresholds. These products will then be disseminated by appropriate communication systems.
- User alerts, advisories, or warnings will be created when user DSTs determine that a 4-D Wx SAS forecast or observed weather variable in an airspace volume of interest exceeds user-set thresholds. Typically this would happen when weather observations or forecasts along a user's approved trajectory unexpectedly change to exceed the user's set threshold. This alert message would likely result in a decision to renegotiate the user's trajectory.

Because of limited storage space and communication bandwidth, 4-D Wx SAS observations will be accessible within operational dissemination and retrieval requirements for 18 hours. Only the two most recent 4-D Wx SAS forecasts will be retained. It will be necessary to archive this information for research and accident investigations and to produce climatological products.

Because an external application is required to use 4-D Wx SAS information, a means for archiving will occur at the location of the application (or the images that were viewed on the application). Policy decisions will determine which 4-D Wx SAS information will be sent to a central archive for permanent storage.

Although NextGen ConOps v2.0 and the Weather ConOps v1.0 were used as foundational documents in this report, the team understood that the concepts within them will be refined. The team also recognized that some areas need additional clarity. The recommendations for updates to these documents are contained in Appendix K.

2.4 NETWORK-ENABLED COMMUNICATIONS

Producers and users of aviation weather information access it via the network infrastructures of the various NextGen partner agencies' networks or via private gateways. Each agency will manage its own weather information access infrastructure. For example, in the case of the FAA, weather information will be managed via services of the System Wide Information Management (SWIM) capability. In the case of DOD, weather information will be managed by services of the Global Information Grid (GIG). These and other agency networks will transfer weather information as needed. Thus, there is no unique weather network, nor is there a single network across which weather information will flow.

The NextGen ConOps v2.0 Executive Summary outlines one of the eight NextGen key capabilities:

> "At the heart of the NextGen concept is the information-sharing component known as net-centric infrastructure services or net-centricity. Its features allow NextGen to adapt to growth in operations as well as shifts in demand, making NextGen a scalable system. Net-centricity also provides the foundation for robust, efficient, secure, and timely transport of information to and from a broad community of users and individual subscribers. This results in a system that minimizes duplication, achieves integration, and facilitates the concepts of distributed decisionmaking by ensuring that all decision elements have exactly the same information upon which to base a decision, independent of when or where the decision is made. The net-centricity component binds NextGen operational and enterprise services together, thereby creating a cohesive link. Enterprise services provide users with a common picture of operational information necessary to perform required functions. The suite of enterprise services includes shared situational awareness (SSA), security, environment, and safety."

Net-centricity is a vital capability for assimilating the common weather picture into the ATM decisionmaking process. The net-centric enterprise services include:

- Ensuring data are visible, accessible, and understandable when and where needed to accelerate decisionmaking
- "Tagging" all data with metadata to enable discovery by known and unanticipated NextGen users
- Posting all data to shared spaces for open and unrestricted access by ATM users.

2.5 GENERAL ASSUMPTIONS AND OTHER CONSIDERATIONS

Concise, complete, and testable functional requirements and performance requirements must be developed to create and manage the 4-D Wx SAS. The team focused on developing these requirements. Leveraging this work, a follow-up team will develop the functional and performance requirements for the 4-D Wx Data Cube (outside of the 4-D Wx SAS). The 4-D Wx SAS spatial and temporal requirements specified in Section 4 will significantly influence the 4-D Wx Data Cube performance requirements.

3 METHODOLOGY

This section discusses how the study team collected and presented the information in this report, including the team members' subject matter expertise, the functional analysis and requirements development training, and the software tools used to produce the diagrams. Early in the study team coordination process, a decision was made to train the team members in formal functional analysis and requirements writing to ensure that a common set of processes would be used as work progressed. Once the training was complete, subteams were created to make the best use of individual team members' subject matter expertise. Details about the training and the subteams are provided in sections below.

3.1 TEAM MEMBERS

The JPDO requested SMEs from FAA, NOAA, NASA, and DOD to participate on the study team. The agencies provided government SMEs and contractors who support the agencies' missions. The SMEs consisted of meteorologists, system engineers, and cost/budget analysts, and some of the SMEs had experience in all three areas. The JPDO felt it was important to have team members who clearly understood NextGen concepts and paradigm, but whose primary responsibility was not NextGen-related. Short biographies of the study team members are provided in Appendix J.

As part of the functional analysis, the study team requested operational user participation from government agencies and industry, but was not able to get dedicated industry representation as requested. However, one of the study team members had air traffic control experience and several of the members were general aviation pilots. More industry participation is vital for future functional and performance requirements work so that user needs can be documented and solutions implemented.

3.2 TRAINING

To enable the team members to perform the assigned tasks, they were trained in functional analysis and requirements development, including how to extract high-level functions from the ConOps and decompose them into lower-level functions and how to develop functional analysis documents (e.g., functional hierarchy). The requirements course provided the techniques for translating functions first into primitive requirements statements and then into functional requirements, as well as the methodology for writing concise, complete, and testable functional and performance requirements.

3.3 GROUP EFFORTS

A majority of the group met in the Washington, D.C. area on a weekly basis for full-day sessions. Members outside of the area participated via telecon or web conferencing. During the group sessions, the ConOps was reviewed, the high-level functions were determined, the scope of the effort was outlined, and updates and feedback from subteam work were provided.

3.4 SUBTEAMS

Because of the time constraints for completing several large and complex tasks, the team decided to break into subteams to better focus on the detailed tasks and to align the team members by subject matter expertise. Details about the various subteams are provided below.

Lexicon. The Lexicon Subteam built a common glossary and acronym list. This enabled a common understanding of the functions needed to create and manage the 4-D Wx SAS.

Observe Weather. The Observe Weather Subteam used the NextGen ConOps v2.0 to determine the high-level "Observe" functions, and decomposed them to the lowest level so the team could determine the 4-D Wx SAS data content.

Forecast Weather. The Forecast Weather Subteam used the NextGen ConOps v2.0 to determine the high-level "Forecast" functions, and decomposed them to the lowest level so the team could determine the 4-D Wx SAS data content.

Traceability. The Traceability Subteam traced the 4-D Wx SAS functions to the NextGen ConOps v2.0, the Weather ConOps v1.0, other documents (i.e., policies, regulations, orders, FAA and NAS EA), and considered SME opinions. This subteam developed a traceability table to record the function ID, function text, applicable ConOps paragraph number, applicable stakeholders, and source traceability code (see Appendix D).

Cube Definition. The Cube Definition Subteam determined the boundaries of the ATM portion of the cube and coordinated with the JPDO Policy Team on a common definition of the cube, the 4-D Wx SAS, and the type of information included in each.

Performance Requirements. The Performance Requirements Subteam developed a set of functional requirements and a limited set of performance requirements for the 4-D Wx SAS, as requested in the TOR specified by the JPDO. The subteam also developed draft functional requirements for the 4-D Wx Data Cube.

Validation Team. The Validation Subteam validated the 4-D Wx SAS functions and weather information contents both previously validated and newly identified, and the requirements derived from the NextGen ConOps v2.0; the Weather ConOps v1.0; various agency documents, orders, regulations, guidance, or analysis; Aviation Mission Need Statement #339; SMEs; and operational user statements (either obtained directly or from user-authored studies or user forums). This subteam developed a small survey to coordinate and validate users' weather needs with various factions of the operational user community or representatives of the user community. The survey was designed to validate:

- Operational user familiarity, understanding, acceptance, or concern with the NextGen ConOps v2.0 and the Weather ConOps v1.0
- A quantification of envisioned operational capabilities in the NextGen that will be affected by weather
- Types of weather information most likely to be more or less important based on the stated envisioned operational capabilities in the NextGen.

Because of the complexity of the validation task and the available time, manpower, and operational user input received, only a portion of the needed validation could be completed. It is understood that further validation of weather-related functions and requirements will be iterative and will evolve as new operational concepts are introduced.

Trajectory-Based Operations. The Trajectory-based Operations (TBO) Subteam identified and incorporated into the 4-D Wx SAS the weather functions needed to support TBO. This subteam reviewed the NextGen ConOps v2.0 and the Weather ConOps v1.0 to develop an initial functions list that included the weather, air traffic, and flight deck functions required to perform TBO. The subteam then derived a final functions list identifying 4-D Wx SAS functions that supported the identified air traffic and flight deck functions of TBO and that may be integrated into DSTs for TBO.

Cost Estimate. The Cost Estimate Subteam performed a SME ROM cost analysis for creating and managing the 4-D Wx SAS. Using the limited performance requirements and the data content requirements for the 4-D Wx SAS derived from the larger team's efforts, the ROM cost analysis was completed with the assistance of SME input largely from the National Center for Environmental Prediction (NCEP).

Final Report Preparation. The Final Report Preparation Subteam organized and prepared the final report by combining information from the various subteams into the final format.

Enterprise Architecture. The EA Subteam developed the NextGen EA weather artifacts (OV-2, OV-5, SV-1, and SV-4) and supported development of the functional hierarchy. This subteam used Telelogic Corporation's "System Architect" to model components of the NextGen EA.

4 4-D WX SAS FUNCTIONAL AND PERFORMANCE REQUIREMENTS

The team's primary task was to provide NextGen weather functional and limited performance requirements for the 4-D Wx SAS. To complete this task, the team performed a detailed functional analysis of the weather capabilities needed to support NextGen operations. A weather functional analysis was performed using Section 4.4 (Functional Analysis) of the FAA Systems Engineering Manual (SEM), which has adopted government and industry best practices. For JPDO agencies to plan and implement NextGen, it is essential to perform a functional analysis to the lowest level and develop the associated functional and performance requirements.

Functional analysis is a system engineering process that determines characteristic actions or activities that must be performed to achieve a desired system objective or stakeholder need. A function describes *what* the system will do, not *how* it will do it. A function name is stated as an action verb followed by a noun or noun phrase; it is an action that describes the desired system behavior. Examples of functions are "read book" or "measure wind speed." Using the functional analysis process significantly improves requirements development, selection of the best physical solution, and integration. Functional analysis improves the acquisition process by discouraging predefined solutions, leads to a complete set of requirements that satisfy stakeholder needs, and enables the incorporation of new and innovative designs and solutions.

Functional analysis is conducted to the level needed to support later design efforts. Each function required to meet the operational needs of a system is identified, defined, and organized into a functional architecture that is used to define system requirements. The process moves to a greater level of detail as the identified functions are further decomposed into subfunctions. This process is repeated until the system (e.g., NextGen) is completely decomposed into basic subfunctions, and each subfunction at the lowest level is translated into a validated set of requirements. The functional analysis process provides two key benefits: (1) it discourages single-point solutions (i.e., a solution looking for a requirement), and (2) it describes the system behaviors that lead to requirements. Functional analysis products included in this report are functional hierarchies, a list of all "Observe" and "Forecast" functions and subfunctions, and data flow to operational users.

This task was redefined by the JPDO Weather Working Group to concentrate on the functions required to provide consistent weather information to support ATM decisionmaking. As part of the team effort, along with input from the JPDO Weather Policy Team, these functions were defined as the 4-D Wx SAS. To determine the 4-D Wx SAS functions, it was necessary to perform a high-level functional analysis for all of NextGen weather-related functions to determine the boundary between the 4-D Wx Data Cube and the 4-D Wx SAS. This was accomplished through a detailed review of the NextGen ConOps v2.0 and the NextGen Weather ConOps v1.0.

NextGen was the system for this task, so the study team extracted operational functions from the NextGen ConOps v2.0 and decomposed them until sufficient detail emerged to determine the high-level weather functions. The study team also extracted weather functions from the NextGen Weather ConOps v1.0. These functions were organized into a functional hierarchy. The functions in the functional hierarchy were numbered to ensure complete traceability through the NextGen EA, as well as the NextGen ConOps, and each function was decomposed a number of

levels. In addition, the Observe Weather and Forecast Weather Subteams performed detailed decomposition of the "Observe Atmospheric and Space Conditions" and "Forecast Weather" functions to determine the data contents of the 4-D Wx SAS. It was important to identify these weather elements because the 4-D Wx SAS will receive all domain authority-approved observations and forecast weather data/information. By doing so, it was possible to better understand the amount and types of data and information that the 4-D Wx SAS will manage. For the function "Run Model/Algorithms" and its subfunctions, among which is the function "Create 4-D Weather SAS," model experts may want to perform a more detailed analysis to determine the lower level functions for this capability. Because the JPDO Wx Working Group Lead decided that the development of the performance requirements would be spread across multiple study teams, the functional requirements study team chose to develop a draft set of NextGen weather functional requirements to aid them in writing the performance requirements.

Weather data/information will be available in the 4-D Wx SAS from the Earth's surface up to an altitude of 500 kilometers (low Earth orbit). However, for the purposes of this functional analysis, the vast majority of observed or forecast weather ceases at the altitude where it no longer has an impact on aviation. An obvious exception is that of space weather, which has solar radiation activity impacting regions well above the atmosphere, as well as into the atmosphere and occasionally at the surface.

The weather functional hierarchy from the top-level services of "NextGen Services F0" through the detailed functions that must be performed to provide necessary NextGen weather information to the lowest weather functions (e.g., "Observe In-flight Icing F1.1.1.1.2.5.4") are shown in Figures 4-1 to 4-5. Since the team was tasked to provide the 4-D Wx SAS weather information content, the "Observe Atmospheric and Space Conditions" and "Forecast Weather" show the most detailed decomposition. Figure 4-1 depicts the "NextGen Services F0" functional hierarchy of the high-level services (functions) using numbering from the NextGen service architecture to ensure traceability. Figure 4-2 depicts the functional hierarchy for "Enterprise Services F1," while Figure 4-3 depicts the "Weather Services F1.1" functional hierarchy. Figure 4-4 and Figure 4-5 depict some of the subfunctions under "Observe Atmospheric and Space Conditions" and "Forecast Weather" respectively, but these subfunctions are so numerous that the total list is provided in Appendix B. "Weather Services F1.1" supports most subfunctions of NextGen Services as well as the functions subordinate to "Enterprise Services F1."

In Figure 4-1, the lower level service areas are depicted directly under "NextGen Services F0." These seven lower level services are "Enterprise Services F1," "Airport Support F2," "Airport Operations F3," "Air Navigation Support F4," "Air Navigation Operations F5," "Flight Support F6," and "Flight Operations F7."

Figure 4-1. NextGen Services F0 Hierarchy

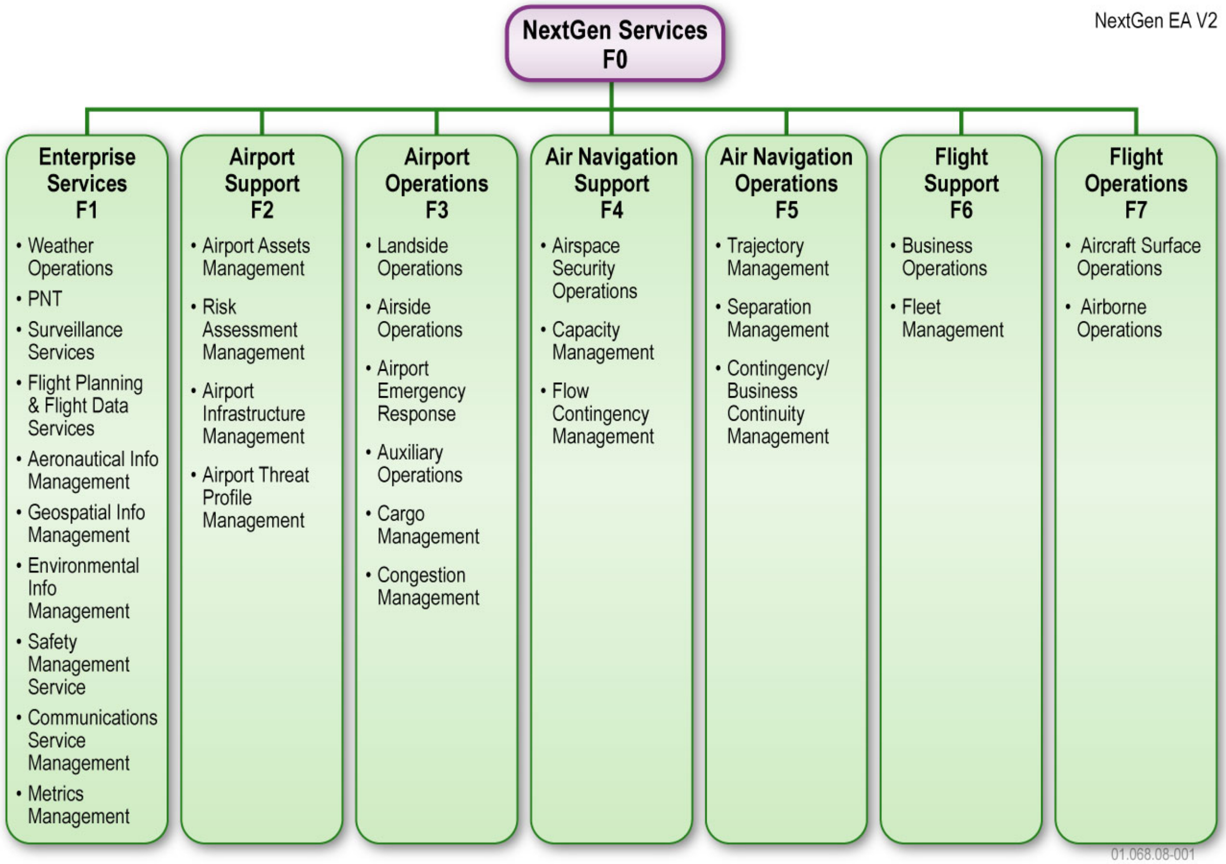


Figure 4-2. Enterprise Services F1 Hierarchy

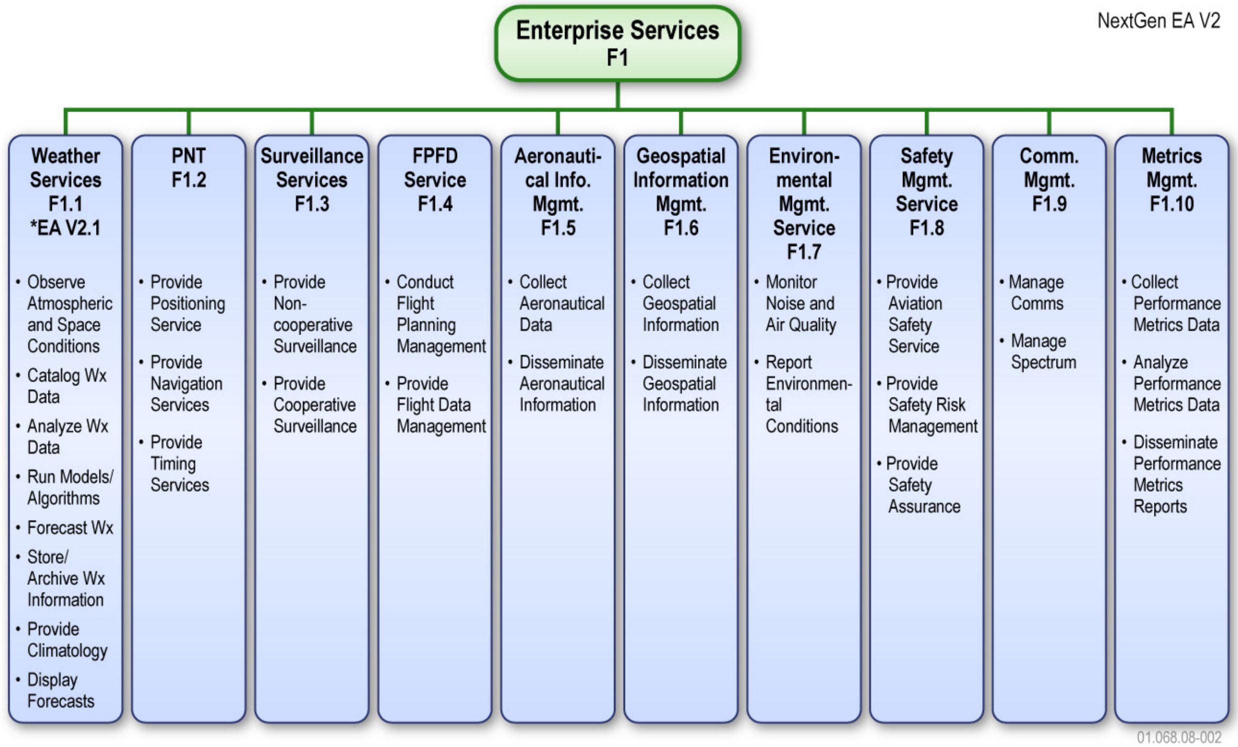


Figure 4-3 represents a further decomposition of Weather Services F1.1, which is the updated name per the EA v2.1. Note that the subfunctions to “Observe Atmospheric and Space Conditions” and “Forecast Atmospheric” functions use different verbs. For example, the subfunction verbs under “Observe” were identified as “Measure,” “Determine,” “Detect,” “Sum,” and “Calculate.” This means that a person or system can “Observe” the wind but must “Determine” or “Measure” the wind speed or wind direction to obtain meaningful information (a discrete value) that is of operational significance. The functions with an asterisk were included in the development of the ROM cost detailed in Section 6.

Although the NextGen ConOps and the NextGen Weather ConOps both envision network-enabled operations and the distribution of weather data via a Publish/Subscribe model, the functional details of this capability and the allocation of those functions to the publishers versus the data transportation managers have not yet been established. Therefore, in Figure 4-3 under “Manage 4-D Weather,” the following subfunctions may not be allocated to the Provide Weather Data Capability: “Manage Weather Subscriptions,” “Manage Subscription Queues,” “Manage Access,” and “Protect Proprietary Weather Information.”

Figure 4-3. Provide Weather Services F1.1 Hierarchy

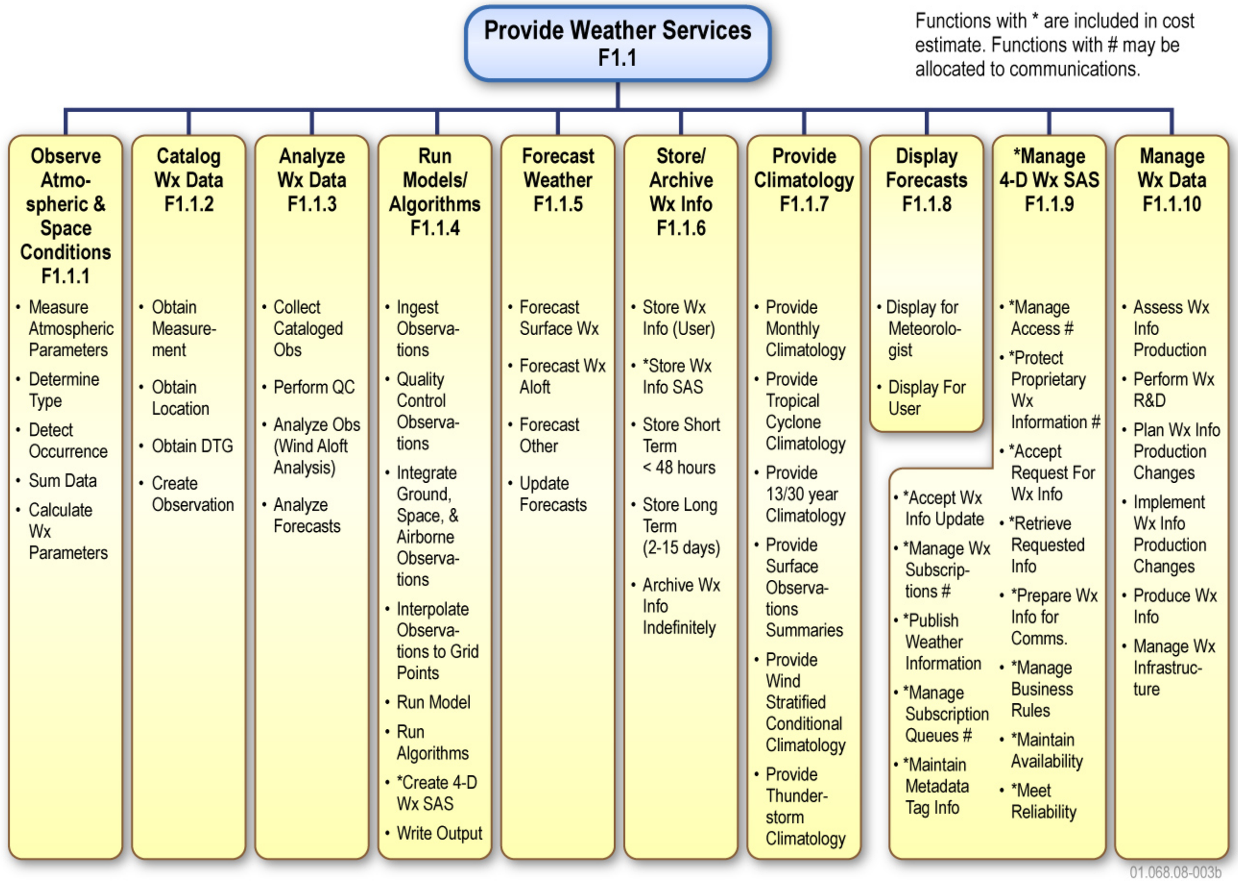


Figure 4-4 and Figure 4-5 show the most detailed decomposition of weather functions "Observe Atmospheric and Space Conditions" and "Forecast Weather." A hierarchical structure for "Observe" and "Forecast" is used to illustrate the parent-child relationship of functions with their subfunctions, and to show traceability back to NextGen Services in Figure 4-1 and Figure 4-2. Many of the "Observe" and "Forecast" (or related) functions apply to spaceports, not just to airports. However, it was not possible to show the hundreds of child functions associated with these two parent functions, so the last function in several rows is "etc." The complete list of functions is detailed in Appendix B.

Figure 4-4. Observe Atmospheric and Space Conditions F1.1.1 Hierarchy

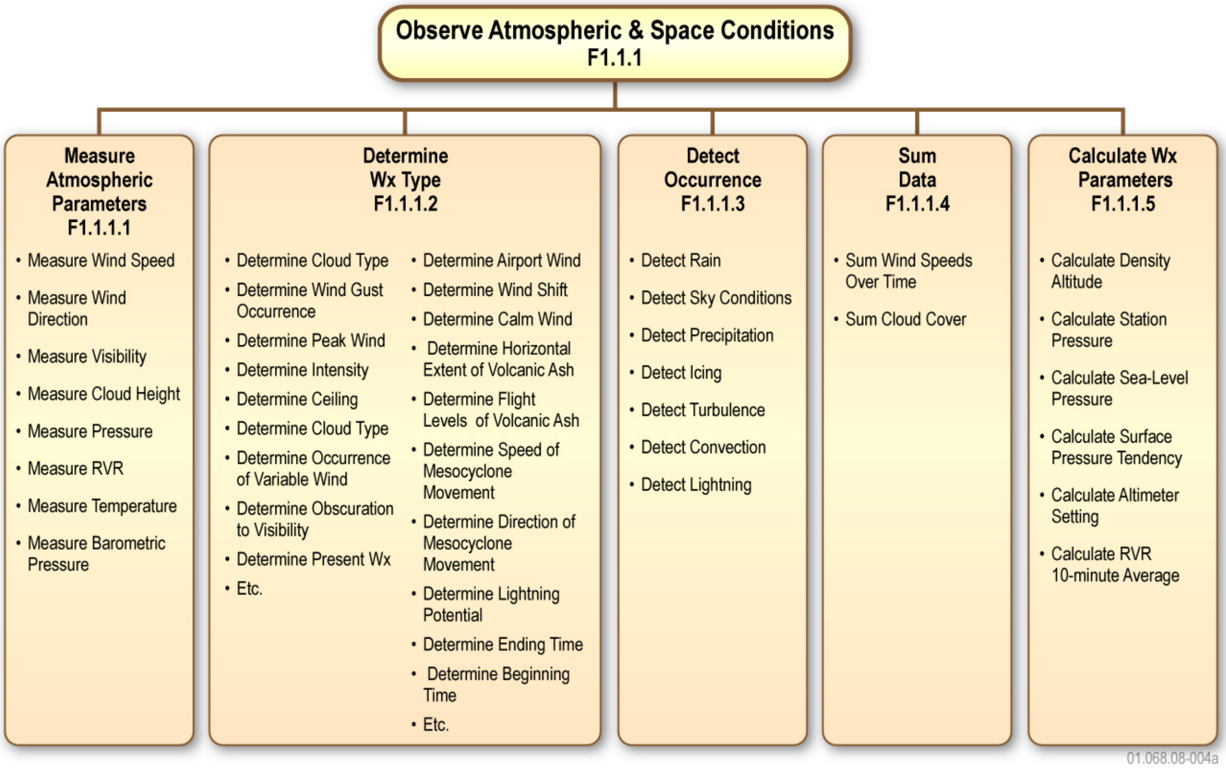
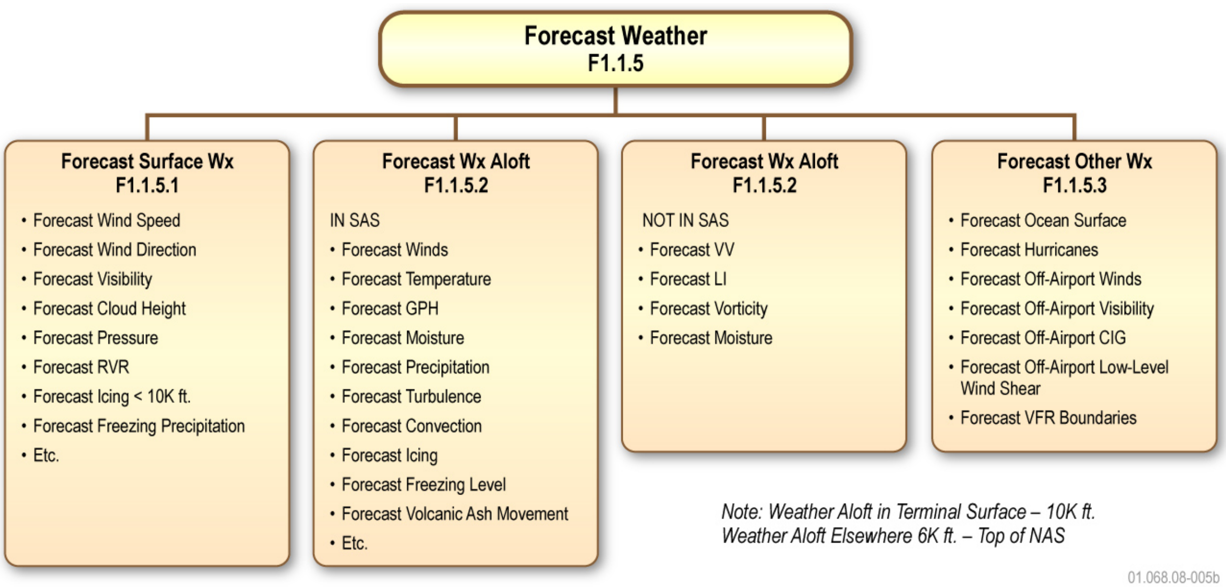


Figure 4-5. Forecast Weather F1.1.5 Hierarchy



To show traceability back to the NextGen ConOps v2.0 for each of the below functions, the team annotated each "Observe" and "Forecast" function (or subfunction) with a symbol that relates to operational subfunctions extracted from the NextGen ConOps. Those operational subfunctions and symbols are as follows:

Provide weather information to support:	Symbol to use for traceability:
Air Traffic Operations	#
Traffic Management (or Capacity) Operations	*
Flight Community (Operators)	^
Terminal Airspace Configuration	~
Ground Operations	%

The "Support Ground Operations" function was decomposed, and the subfunctions were evaluated to determine which ones require weather information to support decisionmaking. For example, one of the subfunctions was "Support Refueling," which would require NextGen to "Observe" and "Forecast" lightning; therefore "%" was appended after the "Observe Lightning" function—"Observe Lightning %." Another "Support Ground Operations" function was "Support Deicing Operations." For airport personnel to make operational decisions in this case would require "Observe Temperature," "Observe Wind Speed," "Observe Ice Accretion Rate," and so forth. Each would have a "%" symbol appended to the end of the line associated with these "Observe" functions. An appropriate symbol was attached after each of the "verb-noun" pairs, provided in Appendix B, to show traceability back to the NextGen ConOps v2.0.

In addition to the five symbols described above to show traceability, the "+" symbol is used to indicate that the parameter will reside within the 4-D Wx Cube, but not the 4-D Wx SAS. Those functions *without* the "+" will reside within the 4-D Wx SAS. For example, "Observe Weather +" is a parent function providing data that resides within the 4-D Wx Cube, a subset of which resides in the 4-D Wx SAS. However, a function identifying the type of weather (e.g., "Determine Liquid Precipitation Type," "Determine Location of Drizzle," or "Determine Snow Fall Rate") that is required by an ATM operational user would reside within the 4-D Wx SAS. The "Observe" and "Forecast" functions are traced up through "Provide Weather Services F1.1" (Figure 4-2) to "Provide NextGen Services." The functional hierarchy shown below begins with the function "Provide NextGen Services F0" and traces down through "Provide Enterprise Services F1," "Provide Weather Services F1.1," to "Observe Atmosphere and Space Conditions F1.1.1."

This functional hierarchy lists only the first few functions of the functional analysis decomposition of the "Observe Weather" and "Forecast Weather" functions. It is intended to provide insight into the methodology used by the Observe Weather and Forecast Weather Subteams to determine the content of weather data/information that will be managed by the 4-D Wx SAS. The full report on Observe Weather and Forecast Weather is provided in Appendix B.

F.0	NextGen Services
F.1	Enterprise Services
F1.1	Provide Weather Services
F1.1.1	Observe[5] Atmospheric and Space Conditions

Note: For brevity from this point forward, the leading F1.1. in the numbering scheme is eliminated, and thus "F1.1.1 Observe Atmospheric and Space Conditions" becomes—

5 Observe = To evaluate or measure, by human or automated means, one or more meteorological elements (e.g., temperature, wind speed/direction, visibility, precipitation) that describe the state of the atmosphere either at the Earth's surface or aloft.

1	Observe Atmospheric and Space Conditions	
1.1	Observe Weather +	
1.1.1	Observe Present Surface Weather	^ # * ~ %
1.1.1.1	Observe Surface Liquid Precipitation +	^ # * ~
1.1.1.1.1	Determine Liquid Precipitation Type	^ #
1.1.1.1.1.1	Determine Location of Drizzle	^ #
1.1.1.1.1.1.1	Determine[6] Horizontal Extent of Drizzle	*
1.1.1.1.1.1.2	Determine Vertical Extent of Drizzle	^ #
1.1.1.1.1.2	Determine Location of Rain	^ #
1.1.1.1.1.2.1	Determine Horizontal Extent of Rain	^ # *
1.1.1.1.1.2.2	Determine Vertical Extent of Rain	^ #

Once the functions associated with the 4-D Wx SAS were defined, the Performance Requirements Subteam developed the functional requirements. They then developed the associated performance requirements per the JPDO TOR (e.g., resolution [spatial and temporal], latency, refresh, reliability, integrity, and information content). The subteam developed 59 functional and performance requirements as required by the TOR. The Performance Requirements Subteam used today's requirements as a baseline and adjusted them based on the evaluation of the weather needed for NextGen operations (e.g., super density and air navigation operations). They also developed draft functional requirements for the rest of the NextGen weather functions. The follow-on study group will develop the rest of the NextGen weather performance requirements. Each functional requirement will have one to three performance requirements associated with it.

Table 4-1 contains specific performance requirements (white background) for functional requirements (blue background) and indicated applications (beige background). On each page, the functional requirement categories, including descriptions and explanatory notes, are listed in the first three rows. Applications are in the first column, and repeat on pages 4-10 through 4-12 each set of functional requirements. A second set of applications appears on page 4-13. The same functional requirements repeat across. Where no specific performance requirement is applicable, the cell is grayed out. Table 4-2 contains functional requirements for systems that store elements of the 4-D Weather SAS.

[6] Determine = To fix conclusively or authoritatively.

Table 4-1. 4-D Wx SAS Functional and Performance Requirements

Function Categories	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy
Notes on functional categories:				***Follow-on group needs to establish accuracy standards for ATM use and to attain primary status.***
Functional Requirements	**The 4-D Weather SAS shall cover the volume of NAS airspace from surface to Low Earth Orbit; The 4-D Weather SAS shall contain forecasts at operationally required spatial resolutions.**		**The 4-D Weather SAS shall provide forecasts at operationally required temporal resolutions.**	**The 4-D Weather SAS shall contain accurate weather information based on operational requirements.**
Application				
Outside NAS	The 4-D Weather SAS shall provide global forecasts at 10 km horizontal resolution.	The 4-D Weather SAS shall contain forecasts with vertical resolution of 500-ft from surface to the top of the NAS (or equivalent).	The 4-D Weather SAS shall contain forecasts in 1-hour increments from 0-60 hours; in 3-hour increments from 60 hours to 14 days	The 4-D SAS shall meet accuracy requirements determined for each weather parameter.
NAS over North America and adjacent coastal waters. Does not include volumes designated as terminal.	For convection the 4-D Weather SAS shall contain forecast at 1km horizontal resolution. For weather elements other than convection, the 4-D Weather SAS shall provide NAS forecasts at 4 km horizontal resolution.		For convection from 0-2 hours, the 4-D Weather SAS shall contain forecasts in 15-minute increments. For all other weather elements, the 4-D Weather SAS shall contain forecasts in 1-hour increments from 0-60 hours; in 3-hour increments from 60 hours to 14 days.	
Terminal (volume of airspace within 50 km of centerfield to top of the terminal volume). See note on page 4-12.	The 4-D Weather SAS shall provide forecasts for airspace designated as *terminal* with 1 km horizontal resolution.	The 4-D Weather SAS shall contain forecasts for airspace designated as terminal: vertical resolution of 500-ft. increments from 5,000 ft. AGL to the top of the terminal volume; 250-ft. increments from 3,000 to 4,750 ft. AGL; and 100-ft. increments from surface to 2,900 ft. AGL within 4 hours of valid time.	For convection from 0-2 hours, the 4-D Weather SAS shall contain forecasts in 10-minute increments. For all other weather elements, the 4-D Weather SAS shall contain forecasts for airspace designated as *terminal:* at 15-minute increments for time 0-4 hours and 1-hour increments from 4 to 60 hours (28), and 6-hour increments from 60 hours to 14 days.	
10-minute increment forecasts				
15-minute increment forecasts				
1-hour increment forecasts				
3-hour increment forecasts				
Climatological forecasts	The 4-D Weather SAS climatological forecasts shall have horizontal resolution to be determined.	The 4-D Weather SAS climatological forecasts shall have a vertical resolution to be determined.	The 4-D Weather SAS shall contain a climatological forecast out to 3 months.	

Table 4-1 (Continued)

Function Categories	Consistency	Probabilistic	Statistical Reliability	Refresh Rate
Notes on functional categories:	*Follow-on group needs to establish standards for consistency*	*Probabilistic criteria to be investigated.*	*Statistical reliability criteria to be investigated*	*Operational needs need to be determined for each aviation-specific weather parameter.*
Functional Requirements	**The 4-D Weather SAS shall contain horizontally and vertically consistent weather information.**	**The 4-D Weather SAS shall contain probabilistic weather information for designated weather parameters.**	**The 4-D Weather SAS probabilistic weather information shall maintain a statistical reliability as specified by operational need.**	**The 4-D Weather SAS shall be updated based on operational needs.**
Application				
Outside NAS				The 4-D Weather SAS shall update forecasts with 1-hour increments every 30 minutes.
NAS over North America and adjacent coastal waters. Does not include volumes designated as terminal.				
Terminal (volume of airspace within 50 km of centerfield to top of the terminal volume). See note on page 4-12.	The 4-D SAS shall meet consistency requirements as determined by the physical representation of the atmosphere.	The 4-D SAS shall meet probabilistic forecast requirements for each aviation-specific weather parameter.	The 4-D SAS shall meet statistical reliability requirements for each aviation-specific weather parameter.	The 4-D Weather SAS shall update volumes designated as terminal every 7.5 minutes. The 4-D Weather SAS shall update 10-minute convective forecasts every 5 minutes.
10-minute increment forecasts				The 4-D Weather SAS shall update forecasts with 10-minute resolution every 5 minutes.
15-minute increment forecasts				The 4-D Weather SAS shall update forecasts with 15-minute resolution every 7.5 minutes.
1-hour increment forecasts				The 4-D Weather SAS shall update forecasts with 1-hour resolution every 30 minutes.
3-hour increment forecasts				The 4-D Weather SAS shall update forecasts with 3-hour increments every 1 hour.
Climatological forecasts				The 4-D Weather SAS shall update climatological forecasts monthly.

Table 4-1 (Continued)

Function Categories	Latency	Availability	Archive	Store
Notes on functional categories:	*Follow-on group to determine latency requirements for each type of aviation weather parameter.*		*Since the 4-D Wx SAS is digital, what is requirement for the application? The 4-D Wx SAS is unaware of how its information is displayed or used.*	*DSTs relying on 4-D Wx SAS information will increase in number next decade.*
Functional Requirements / **Application**	**The 4-D Weather SAS shall be continuously accessible to users**	**The 4-D Weather SAS shall meet reliability standards set by operational users including information needed for critical and essential operations**	**The 4-D Weather SAS shall make available data for archiving.**	**The 4-D Weather SAS shall store weather information for integration into operational users' decision support tools.**
Outside NAS	The 4-D Weather SAS shall update forecasts with 1-hour resolution within 30 minutes of valid time.		The 4-D Weather SAS shall make information available for permanent archiving as prescribed. The 4-D SAS weather information shall be archived at the resolution as it is in the 4-D Wx SAS.	The 4-D Weather SAS shall store weather observations and analyses for 18 hours. The 4-D Weather SAS shall store only the last two scheduled forecast issuances, including all associated corrections and amendments.
NAS over North America and adjacent coastal waters. Does not include volumes designated as terminal.	The 4-D Weather SAS shall update forecasts with 1-hour resolution within 30 minutes of valid time. **The 4-D Weather SAS shall update 15-minute convective forecasts within 7.5 minutes of valid time.**			
Terminal (volume of airspace within 50 km of centerfield to top of the terminal volume). See note on page 4-12.	The 4-D Weather SAS shall update volumes designated as terminal within 7.5 minutes of valid time. **The 4-D Weather SAS shall update 10-minute convective forecasts within 5 minutes of valid time.**			
10-minute increment forecasts	The 4-D Weather SAS shall update forecasts with 10-minute resolution within 5 minutes of valid time.			
15-minute increment forecasts	The 4-D Weather SAS shall update forecasts with 15-minute resolution within 7.5 minutes of valid time.			
1-hour increment forecasts	The 4-D Weather SAS shall update forecasts with 1-hourly resolution within 30 minutes of valid time.			
3-hour increment forecasts	The 4-D Weather SAS shall update forecasts with 3-hourly increment within 90 minutes of valid time.			
Climatological forecasts	The 4-D Weather SAS shall update climatological forecasts within 1 day of valid time.			

Table 4-1 (Continued)

Function Categories ***Notes on functional categories:***	**Notes and Comments on Applications**
Functional Requirements	
Application	
Outside NAS	
NAS over North America and adjacent coastal waters. Does not include volumes designated as terminal.	*NCEP estimate includes 2.5km resolution over CONUS & AK. Just as easy to do as 4km.*
Terminal (volume of airspace within 50 km of centerfield to top of the terminal volume). See note at right.	*Cost estimate based on 96 terminals every 15 minutes. May need to expand to 100km radius. If 100km, may only need 35 OEP airports. ATO-R cited possible need for 1-minute temperature resolution for first 15 minutes.*
10-minute increment forecasts	
15-minute increment forecasts	
1-hour increment forecasts	
3-hour increment forecasts	
Climatological forecasts	*Climatological forecasts needed for: Thunderstorm, Icing, Turbulence, Ceiling, and Visibility.*

Table 4-1 (Continued)

Function Categories	Latency	Availability	Notes and Comments	Store
Notes on functional categories:	*Follow on group to determine latency requirements for each type of aviation weather parameters*			*DSTs relying on 4-D Wx SAS information will increase in number next decade.*
Functional Requirements **Application**	**The 4-D Weather SAS shall be continuously accessible to users**	**The 4-D Weather SAS shall meet reliability standards set by operational users including information needed for critical and essential operations**	**The 4-D Weather SAS shall make available data for archiving.**	**The 4-D Weather SAS shall store weather information for integration into operational users' decision support tools.**
Essential Service—Function or service that if lost would reduce the capability of the NAS to exercise safe separation and control over aircraft	0.999	The 4-D Weather SAS shall have a MTTR of .5 hours. The 4-D Weather SAS shall have an MTBF of 5,000 hours; The 4-D Weather SAS shall have no loss of service that exceeds one per week. The 4-D Weather SAS shall not have a loss of service for essential weather information that exceeds 10 minutes.	Need to determine if the 4-D Wx SAS will contain any critical information weather information. SME ROM did not assume critical weather information is in the 4-D Wx SAS.	
Critical service—Function or service that if lost would prevent the NAS from exercising safe separation and control over aircraft	0.99999	The 4-D Weather SAS shall have a MTTR of .5 hours, The 4-D Weather SAS shall have an MTBF of 50,000 hours; The 4-D Weather SAS shall have no loss of service that exceeds one per week; The 4-D Weather SAS shall not have a loss of service for critical weather information that exceeds 6 seconds.		

Table 4-2. Functional System Requirements for the 4-D Wx SAS

System Requirements the 4-D Weather SAS
The 4-D Weather SAS shall manage subscriptions.
The 4-D Weather SAS shall manage publication of weather information.
The 4-D Weather SAS shall manage subscription queues.
The 4-D Weather SAS shall maintain metadata for weather information.
The 4-D Weather SAS shall protect proprietary information.
The 4-D Weather SAS shall prepare weather information for communication with user.
The 4-D Weather SAS shall provide security for weather information.
The 4-D Weather SAS shall manage business rules.
The 4-D Weather SAS shall make new information available to NEO capability within 10 seconds of receipt.

5 CAPABILITIES AVAILABLE IN 2012, 2016, AND 2020

The JPDO provided TOR that directed the Weather Functional Requirements Study Team to document consolidated NextGen 4-D Cube functional requirements for the 2012, 2016, and 2020 time horizons. These requirements were to contain sufficient detail for 2012 to allow agency cost-benefit analysis, budgeting, and planning actions to support development of agency FY10 budgets.

The success of the 4-D Wx SAS depends on its ability to provide weather information that NextGen operations need to increase capacity of the NAS while maintaining safety. The key to this will be twofold:

1) The availability of weather information in the *appropriate timeframe* so that the delivery of the information is matched with the operational readiness for proof of capability. This means that required weather information is available when the decision-support tool or other ATM functionality is operationally ready to deliver the NextGen capability.
2) The availability of weather information containing *required performance characteristics* needed to deliver the capability. Simply put, not just *any* weather information will suffice. Weather will be just one of the inputs to a NextGen capability. The performance characteristics of the weather information need to be *tuned* with these other non-weather inputs.

The study team addressed the first key component above. A follow-on team will need to address the second key component. It is beyond the scope of this effort to describe how to integrate weather information into decision tools or functions. However, the study team leveraged the draft results of the JPDO Forecast, Integration, Dissemination, and Observation (FIDO) Team to gain a better understanding of the types of weather-related capabilities the team envisioned by 2012. These capabilities were driven by the FIDO team's expertise in weather technology advances and its understanding of the potential benefits offered to NextGen operations through the mitigation of weather in the NAS.

The study team also leveraged the first version of the Integrated Work Plan (IWP), which contained all operational improvements (OI) and enablers (not just weather) envisioned to support NextGen capabilities. The consistency between the draft FIDO report and the IWP and the connection between planned weather capabilities (weather enablers) and non-weather enablers or OIs that are supported by weather information, were noted.

Based on these initial reports, the study team matched planned 4-D Wx SAS functionality and data content with those OIs in the timeframes envisioned for implementation. It is understood that OI and enabler language for weather and non-weather functional areas has changed several times since the FIDO effort and the first IWP version (summer 2007). This has been driven mostly by a better understanding of envisioned capabilities, clarity of language, and so forth. It is also acknowledged that NextGen concept development is an iterative process and will be affected by technology, budget (including cost to envisioned benefit), and policy, etc. The follow-on team can leverage the next version of the IWP, as well as a clearer identification of weather enabler trace. This will help 4-D Wx SAS functions and weather performance characteristics to converge with the OIs they support.

The status of the 4-D Wx SAS at 2012, 2016, and 2020 was considered separate from the status of network-enabled communications. The status of the FAA's SWIM at 2012 is uncertain. There is also uncertainty about NOAA's ability to network-enable 4-D Wx SAS information sets it will be providing by 2012. Additional funding will ensure that agency Net-enabled Operations (NEO) capability will coincide with 4-D Wx SAS readiness for a limited number of weather information sets.

The status of the 4-D Wx SAS was also considered separately from the status of operational applications that will use this information through network-enabled communications. The following three capabilities should be ready:

- The Conflict Probe Capability currently provided by the User Request Evaluation Tool (URET) assists air traffic controllers with timely detection and resolution of predicted conflicts. By helping to manage controller workload and allowing increased strategic planning, it enables the system to support a greater number of user-preferred flight profiles, increases user flexibility, and increases system capacity while maintaining the required level of safety.
- Major airport flow control capability currently provided by the Traffic Management Advisor (TMA) is a set of tools designed to help air traffic controllers manage the increasingly complex air traffic flows at large airports. This capability benefits air traffic controllers by reducing workload stress and air travelers by reducing delays and increasing safety.
- Strategic Traffic Flow Management capabilities envisioned for the Traffic Flow Management Modernization (TFM-M) program will enhance information sharing between commercial aviation system users and improve system-wide cooperative and collaborative planning, decisionmaking, and congestion management.

At 2012, a limited NEO-ability and a limited number of applications available to use 4-D Wx SAS data means that only a subset of all planned aviation weather elements will need to be available. Nevertheless, many of the functional requirements and performance requirements must be in place for initial capability to be declared *operational*. These requirements are identified in Table 5-1 as "2012 on limited basis."

At a minimum, the following aviation-specific weather parameters should be available by 2012: turbulence, icing, convection, ceiling, visibility, and wake vortex displacement. Currently, four-dimensional gridded data is already available for all parameters except wake vortex, and additional work is progressing. As noted in Table 5-1, user-based accuracy and consistency measures will need to be developed to measure and validate the integrity of the data.

By 2016 much of the research to produce and use high-resolution weather information will be in place or approaching readiness. Only a few functionalities such as the production and use of probabilistic forecasts will not be available until full 4-D Wx SAS capability at 2020.

Table 5-1. Recommended Implementation Dates for Requirements and Traceability to OIs

Functional Analysis				
Proposed 4-D Weather SAS Performance Requirement	**Function Category**	**Implementation Date**	**Note/Definition**	**Operational OIs Supported (Partial List)**
Functional Requirements				
The 4-D Weather SAS shall contain accurate weather information based on operational requirements.	Accuracy	TBD for each: 2012, 2016, 2020	Follow-on group needs to establish accuracy standards for operational ATM use and to attain primary* status.	OI-0351: Airspace Reconfiguration—Dynamic En Route
The 4-D Weather SAS shall make available data for archiving.	Archiving	2012 on limited basis, fully operational 2016		OI-0351: Airspace Reconfiguration—Dynamic En Route
The 4-D Weather SAS shall be available during critical and essential operations.	Availability	2012 on limited basis, fully operational 2016	Critical service—Function or service, that if lost, would prevent the NAS from exercising safe separation and control over aircraft.	OI-0358: Trajectory-Based Management
The 4-D Weather SAS shall maintain availability required by operational users.	Availability	2012 on limited basis, fully operational 2016	Need to identify weather information that is critical or essential	OI-0358: Trajectory-Based Management
The 4-D Weather SAS shall meet reliability standards set by operational users.	Availability	2012 on limited basis, fully operational 2016	Need to evaluate if any weather information is critical or essential	OI-0358: Trajectory-Based Management
The 4-D Weather SAS shall contain horizontally and vertically consistent weather information.	Consistency	2012 on limited basis, fully operational 2016	Follow-on group needs to establish standards for *consistency*.	Various as performance need dictates
The 4-D Weather SAS shall be continuously accessible to users.	Latency	2016	Follow-on group to determine latency requirements for each type of aviation weather parameter.	Various as performance need dictates
The 4-D Weather SAS shall contain probabilistic weather information for designated weather parameters.	Probability	2016 on limited basis, fully operational 2020	Probabilistic criteria to be investigated.	Various as performance need dictates
The 4-D Weather SAS shall be updated based on operational needs.	Refresh	2012 on limited basis, fully operational 2016	Operational needs need to be determined for each weather element.	Various
The 4-D Weather SAS shall cover the volume of NAS airspace from surface to Low Earth Orbit.	Spatial Resolution	2012 (limited parameters)		Various
The 4-D Weather SAS shall provide forecasts at operationally required spatial resolutions.	Spatial Resolution	Resolution requirements will increase toward full requirement by 2025		Various OIs as driven by functional performance needs
The 4-D Weather SAS probabilistic weather information shall maintain a statistical reliability as specified by operational need.	Statistical Reliability	TBD for each: 2016, 2020	Statistical reliability criteria to be investigated.	Various as performance need dictates

Table 5-1 (Continued)

Functional Analysis				
Proposed 4-D Weather SAS Performance Requirement	**Function Category**	**Implementation Date**	**Note/Definition**	**Operational OIs Supported (Partial List)**
Functional Requirements				
The 4-D Weather SAS shall store weather information for integration into operational users' decision support tools.	Store	2012 on limited basis, fully operational 2016	DSTs relying on 4-D Wx SAS information will increase in number next decade.	Various
The 4-D Weather SAS shall provide security for weather information.	System	2012	4-D Weather SAS will be secure when first operational.	Function facilitates performance needs of various OIs
The 4-D Weather SAS shall manage subscriptions.	System	2012 on limited basis, fully operational 2016		Function facilitates performance needs of various OIs
The 4-D Weather SAS shall manage publication of weather information.	System	2012 on limited basis, fully operational 2016		Function facilitates performance needs of various OIs
The 4-D Weather SAS shall manage subscription queues.	System	2012 on limited basis, fully operational 2016		Function facilitates performance needs of various OIs
The 4-D Weather SAS shall maintain metadata for weather information.	System	2012 on limited basis, fully operational 2016		Function facilitates performance needs of various OIs
The 4-D Weather SAS shall protect proprietary information.	System	2012 on limited basis, fully operational 2016		Function facilitates performance needs of various OIs
The 4-D Weather SAS shall prepare weather information for communication with user.	System	2012 on limited basis, fully operational 2016	If interpolation is needed, user system must perform according to user-designed scheme.	Function facilitates performance needs of various OIs
The 4-D Weather SAS shall manage business rules.	System	2012 on limited basis, fully operational 2016		Function facilitates performance needs of various OIs
The 4-D Weather SAS shall provide forecasts at operationally required temporal resolutions	Temporal Resolution	Resolution requirements will increase toward full requirement by 2025		Various OIs as driven by functional performance needs

Table 5-1 (Continued)

Proposed 4-D Weather SAS Performance Requirement	Function Category	Implementation Date	Note/Definition	Operational OIs Supported (Partial List)
Functional Analysis				
Performance Requirements				
The 4-D Weather SAS shall contain weather information that meets accuracy requirements for each aviation-specific weather parameter.	Accuracy	2012 to meet ATM accuracy standards, 2016 for Primary* accuracy standards		Various as performance need dictates
The 4-D Weather SAS shall make information available for permanent archiving as prescribed.	Archiving	2012 for 4-D Wx SAS weather information declared operational. 2020 all operational weather information.	Granularity TBD. Also, because the 4-D Wx SAS is digital and does not control how the data will be viewed, display applications (e.g., for accident investigations, performance reviews, etc.) are not determined.	OI-3003: Integrated Safety Assurance and Risk Management
The 4-D Weather SAS loss of service for weather information used in critical decision shall not exceed 6 seconds.	Availability	2012	Critical service—Function or service that if lost, would prevent the NAS from exercising safe separation and control over aircraft.	OI-0358: Trajectory-Based Management
The 4-D Weather SAS loss of service for essential weather information shall not exceed 10 minutes.	Availability	2012		OI-0358: Trajectory-Based Management
The 4-D Weather SAS frequency of occurrence for any loss of service shall not exceed one per week.	Availability	2012		OI-0358: Trajectory-Based Management
The 4-D Weather SAS weather information input into NDOTS for separation assurance shall have an availability of .99999.	Availability	2012	Weather information for DSTs that is used for separation assurance may be considered critical. Evaluation is needed.	OI-0358: Trajectory-Based Management
The 4-D Weather SAS will meet consistency requirements determined for each aviation-specific weather parameter.	Consistency	2012 on limited basis, fully operational 2016		Various
The 4-D Weather SAS shall update forecasts with 10-minute resolution within 5 minutes of valid time.	Latency	2016	Limited product suite likely to be available by 2012 (CWIS)	I-0351: Airspace Reconfiguration—Dynamic En Route
The 4-D Weather SAS shall update forecasts with 15-minute resolution within 7.5 minutes of valid time.	Latency	2016	Limited product suite likely to be available by 2012 (CWIS)	I-0351: Airspace Reconfiguration—Dynamic En Route
The 4-D Weather SAS shall update 1-hourly incremented forecasts within 30 minutes of run time.	Latency	2016		OI-0337: Flow Corridors
The 4-D Weather SAS shall update 6-hourly global forecasts within 2 hours of model run time.	Latency	2016	R&D to determine if a 3 - hourly global forecast available within 2 hours of runtime has any reduction in accuracy that would affect user operations	OI-0351: Airspace Reconfiguration—Dynamic En Route

Table 5-1 (Continued)

Proposed 4-D Weather SAS Performance Requirement	Function Category	Implementation Date	Note/Definition	Operational OIs Supported (Partial List)
Functional Analysis				
Performance Requirements (Continued)				
The 4-D Weather SAS shall provide weather information within 10 seconds of a request.	Latency			Various
The 4-D Weather SAS shall have a MTTR** of .5 hour.	Maintainability			OI-0358: Trajectory-Based Management
The 4-D Weather SAS shall update forecasts with 10-minute resolution every 5 minutes.	Refresh	2016		OI-0311: Enhance Arrival/Departure Routing and Access
The 4-D Weather SAS shall update forecasts with 15-minute resolution every 7.5 minutes.	Refresh	2016		OI-0355: En Route Airborne Merging and Spacing
The 4-D Weather SAS shall update 1-hour incremented forecasts every 30 minutes.	Refresh	2012		OI-0036: Airspace/Capacity/Flow Contingency Management Decisions
The 4-D Weather SAS 6-hourly global forecasts shall be updated every 3 hours.	Refresh			OI-0036: Airspace/Capacity/Flow Contingency Management Decisions
The 4-D Weather SAS shall update the climatological forecasts monthly.	Refresh	2012		OI-6019: Mitigate impacts of aviation on climate
The 4-D Weather SAS shall have an MTBF** of 5,000 hours.	Reliability			OI-0358: Trajectory-Based Management
The 4-D Weather SAS shall contain forecasts for airspace designated as terminal: vertical resolution of 500-ft. increments from 5,000 ft. AGL to the top of the terminal volume; 250-ft. increments from 3,000 to 4,750 ft. AGL; and 100-ft. increments from surface to 2,900 ft. AGL within 4 hours of valid time.	Spatial Resolution	2012		OI-0307: Airspace reconfiguration—Limited Dynamic Arrival/Departure OI-0339: Integrated Arrival/Departure and surface traffic management for Metroplex

Table 5-1 (Continued)

Proposed 4-D Weather SAS Performance Requirement	Function Category	Implementation Date	Note/Definition	Operational OIs Supported (Partial List)
Functional Analysis				
Performance Requirements (Continued)				
The 4-D Weather SAS shall contain forecasts with vertical resolution of 500 feet from surface to the top of the NAS or equivalent for airspace not designated terminal	Spatial Resolution	2012	Based on separation rules	OI-0307: Airspace reconfiguration—Limited Dynamic Arrival/Departure, OI-0351: Airspace Reconfiguration - Limited Dynamic En Route
The 4-D Weather SAS shall provide forecasts for airspace designated as terminal with 1 km horizontal resolution.	Spatial Resolution	NCEP estimates supporting 2 terminals in 2010 up to 175 by 2025	Further investigation may reveal need for larger terminal airspace volume.	OI-0313: Virtual Towers; OI-0327: Surface Management Operations; OI-0328: Wake-based Spacing, Dynamic Drift; OI-0339: Integrated Arrival/Departure and Surface Traffic Management for Metroplex; OI-0340: Zero-Visibility Surface Operations; OI-5006: Coordinated Ramp Operations; OI-5006: Airport GSE Surface Management System; OI-5009: Airside Resource Management System
The 4-D Weather SAS shall provide terminal forecasts within 50 km of designated airports.	Spatial Resolution	Limited 2012, fully operational 2016 (some elements less than 1km resolution)	Further investigation may reveal need for larger terminal airspace volume.	OI-0339: Integrated Arrival/Departure and Surface Traffic Management for Metroplex
For convection the 4-D Weather SAS shall contain forecasts at 1 km horizontal resolution. Otherwise the 4-D Weather SAS shall provide NAS forecasts at 4 km horizontal resolution (non-Oceanic FIRs).	Spatial Resolution	Reach 2.5km by 2025 over non-oceanic FIRs		OI-0035: Separation Management Capability
The 4-D Weather SAS shall provide global forecasts at 10 km horizontal resolution (includes Oceanic FIRs).	Spatial Resolution			OI-0304: Improved Collaborative Oceanic Routing
For convection from 0-2 hours, the 4-D Weather SAS shall contain forecasts in 10-minute increments at designated airports. Otherwise, the 4-D Weather SAS shall contain terminal forecasts out to 4 hours in 15 minute increments	Temporal Resolution	2012	ROM cost based on 96 airports. 35 OEP airports by 2012. ATM SMEs recommended 1-minute granularity for first 15 minutes and 5-minute granularity for minutes 15 through 45.	OI-0313: Virtual Towers; OI-0331: Integrated Arrival/ Departure and Surface Traffic Management; OI-0307: Airspace Recon-figuration—Limited Dynamic Arrival/Departure; OI0355: En Route Airborne Merging and Spacing

Table 5-1 (Continued)

Functional Analysis				
Proposed 4-D Weather SAS Performance Requirement	**Function Category**	**Implementation Date**	**Note/Definition**	**Operational OIs Supported (Partial List)**
Performance Requirements (Continued)				
For convection from 0-2 hours, the 4-D Weather SAS shall contain forecast in 15-minute increments over the NAS. Otherwise, the 4-D Weather SAS shall contain forecasts covering the NAS in 1-hour increments out to 60 hours.	Temporal Resolution	2012		OI-0351: Airspace Reconfiguration—Dynamic En Route
The 4-D Weather SAS shall contain global forecasts in 6-hour increments from 60 hours to 14 days.	Temporal Resolution	2012		OI-2013: Automated Assist Flight Plan Negotiation
The 4-D Weather SAS shall contain a climatological forecasts out to 3 months.	Temporal Resolution	2012	Parameters specified when performance requirements are developed. Evaluate whether in the 4-D Wx SAS.	OI-6019: Mitigate impacts of aviation on climate
The 4-D Weather SAS shall provide forecasts at operationally required temporal resolutions.	Temporal Resolution	Resolution requirements will increase toward full requirement by 2025	Increased funding may be able to speed up to 2020.	Various OIs as driven by functional performance needs
Note: These weather parameters are expected to be 4-D network-enabled and operational by 2012: Convection, Icing, Turbulence, Ceiling/Visibility, Detection of wake vortex on departure for limited airports (ref: “NGATS Network Enabled Weather Initial Operating Capability Definition,” Version N, Dated 2006 (Draft))				
* Primary Weather Product. An aviation weather product that meets all the regulatory requirements and safety needs for use in making flight-related, aviation weather decisions. (Aeronautical Information Manual Safety of Flight 7-1-3 (i.1)				
** MTTR = Mean Time to Repair, MTBF = Mean Time Between Failures				

6 SME ESTIMATED ROM COSTS

The team developed and documented cost, schedule, and performance attributes at the task level for the 4-D Wx SAS. Using comparables for the development and implementation of the 4-D Wx SAS, SMEs estimated the ROM costs. The NWS NCEP prepared the estimate on the development of the capability to create the weather information in the 4-D Wx SAS and the operational cost associated with this capability. NWS provided a SME to develop a cost estimate using today's modeling development and system operations as a comparable to determine the cost of meeting the 4-D Wx SAS functional and performance requirements cited in Section 4. The costs to implement the 4-D Wx SAS infrastructure and associated operations were developed using the operational costs from the Aviation Weather Center's Aviation Digital Data Service.

As described in Section 1.1.1, cost estimates consider the following four functions:

- Store Weather Information
- Manage 4-D Weather SAS
- Generate 4-D Wx SAS Weather Information
- Format Weather Information (for Storage within the 4-D Wx SAS).

The "Store Weather Information" function entails retaining information in such a way that it can be retrieved quickly and easily. It is reasonable to expect the timeframe of this function to range from real time to 18 hours, after which the information will be archived. At this time it has not been determined where the weather information will be physically archived. Costs considered for this function included hardware such as servers, overhead costs (power and cooling), and technical refresh (replacement), and it is estimated that the cost will be $1.5 million annually based on current Aviation Weather Center operation costs.

The "Manage 4-D Weather SAS" function covers movement of information in response to scheduled and non-scheduled user requests. Costs considered for this function include system management, hardware and software maintenance, monitoring, security, backup, and technical refresh and are estimated at $6 million per year. In addition, the total figure also includes the cost of personnel required to maintain the system, which is estimated at $5.5 million. Thereby, the cost estimate for this function is $11.5 million annually.

The team focused significant attention on the "Generate 4-D Wx SAS Weather Information" function, concentrating primarily on NextGen temporal and spatial resolution requirements for 2025. Accordingly, NCEP developed ROM cost estimates to demonstrate the requirements for hosting a similar functionality within an organization, using an existing but improved infrastructure. The information was prepared in a manner that allows flexibility to change the assumptions and update cost accordingly. The ROM cost includes the creation and operation of the capability to produce the weather information for the 4-D Wx SAS. It is estimated at $30 million annually, beginning in 2010 (above the current operating budget of $20 million), to meet the NextGen requirements and maintain the current suite of weather forecast and guidance products. Table 6-1 summarizes items covered by the proposed NextGen costs. A more detailed cost estimate for this function appears in Appendix L.

Table 6-1. "Generate 4-D Wx SAS" Detailed Costs

Current Computing Budget $20M per year covers:	CPUs and Memory	Interconnect Fabric	Operating System	File System	Software & Licenses	Disks & Controllers	System Admin	Application Specialists	Comm.
Additional $20M per year to cover:	CPUs and Memory	Interconnect Fabric	Operating System	File System	Software & Licenses	Disks & Controllers	System Admin	Application Specialists	Comm.
Additional $5M for Facility Expenses	Floor Space	Power	Heating	Cooling	Building Security	Extra comm. Infrastruc-ture			
Additional $1.5M for IT Security		Currently 7.5%							
Additional $2.1M for EMC development personnel									
Additional $1.4M for NCO O&M personnel									

As shown in Table 6-1, approximately $20 million will be used to upgrade current computing capacity to meet the requirements detailed in Section 4. An additional $5 million will be needed to improve facilities to house the supercomputer upgrades. The remaining $5 million will be used for additional information technology security and to cover personnel costs for the development of Terminal models and the improvement of current aviation models.

The ROM was developed based on costs for previous model and supercomputer developments. The comparable models included the Rapid Update Cycle (RUC), Short-Range Ensemble Forecast (SREF), and current improvements to the Global Forecast System (GFS). The comparable models were used to develop a cost estimate of the Terminal Approach models. The reduction in horizontal resolution is based on current costs associated with improved horizontal resolution of a range of NCEP product suites. Estimated costs for the supercomputing and related facilities were determined by using the Jigsaw Methodology, which is an industry standard for determining processing capacity for multiple programs running on a supercomputer. Table 6-2 summarizes the forecast improvements (e.g., resolution, refresh rate, and latency) to NextGen based on the funding increase beginning in 2010. If the number of terminals with the required latency must be available in an earlier time frame (e.g., 28 terminal in 2020), then the cost will increase.

Table 6-2. Spatial and Temporal Resolution Improvements to Meet NextGen Requirements

		2010	2012.5	2015	2017.5	2020	2022.5	2025
Global GFS	Updates per day	4	8	8	8	8	8	8
	Forecast Range (Hours)	168	168	168	168	168	168	168
	Forecast Start Time (Minutes)	200	200	90	90	90	90	90
	Delivery Time (Minutes)	245	245	135	130	130	130	120
	Horizontal Resolution (km)	35	28	23	19	15	12	10
Regional NAM	Updates per day	4	8	8	8	8	8	8
	Forecast Range (Hours)	60	60	60	60	60	60	60
	Forecast Start Time (Minutes)	90	90	90	95	95	95	95
	Delivery Time (Minutes)	140	140	135	135	130	125	120

		2010	2012.5	2015	2017.5	2020	2022.5	2025
	Horizontal Resolution (km)	12	11	10	9	8	7	6
En Route CONUS & AK	Updates per day	24	24	24	24	24	24	24
	Forecast Range (Hours)	12	60	60	60	60	60	60
	Forecast Start Time (Minutes)	25	25	25	25	20	20	15
	Delivery Time (Minutes)	60	50	50	45	35	35	30
	Horizontal Resolution (km)	6	5.5	4.5	4	3.5	3	2.5
Terminal	Updates per day		96	96	96	96	96	96
	Forecast Range (Hours)		4	4	4	4	4	4
	Forecast Start Time (Minutes)		3	3	3	3	3	3
	Delivery Time (Minutes)		8	8	8	8	8	8
	Horizontal Resolution (km)		1	1	1	1	1	1
	Number of Terminals		2	4	11	28	70	175

The "Format Weather Information" function was the final one estimated, and it involved configuring information to comply with various standards of storage. At this point, the team believes all formatting except for storage will be performed by applications outside the 4-D Wx SAS. Storage cost is estimated at $2.5 million.

A summary of the ROM costs for planning purposes is provided in Table 6-3.

Table 6-3. ROM Costs

Function	Cost ($ million/year)
Store Weather Information	1.5
Manage 4-D Weather SAS	11.5
Generate 4-D Wx SAS Weather Information	30
Format Weather Information for Storage	2.5
Total	45.5

The ROM for developing the capability to create the integrated and consistent observation, analysis, and forecast data set for 4-D Wx SAS was $30 million per year. Of that amount, 93 percent was allocated for implementation and operations and 7 percent for the development of the capability to create an integrated and consistent observation, analysis, and forecast data set for the 4-D Wx SAS. The cost to implement and operate the 4-D Wx SAS infrastructure is estimated at $11.5 million per year. The cost to format data for storage is $4 million. The final ROM for the 4-D Wx SAS is $45.5 million per year. Further analysis will be required to refine these ROM numbers.

7 RISKS

The ability to achieve NextGen goals depends in part on the effective integration of weather information into NAS processes. The transformation from today's processes to those described in the NextGen ConOps v2.0 has both technological and organizational challenges. During the requirements formulation process, the study team identified these risks to the transformation:

- Improvements in weather information may take longer than expected to work together with new air traffic management decision systems and tools. The process of designing new weather information for the most effective fit with the new air traffic management systems will be iterative.
- Funds may not be available to implement NextGen as described in the ConOps. Subsequent trade-offs may be required. For example, lack of funds to network-enable each data source may require the pursuit of more efficient engineering designs that may not match the descriptions provided in the NextGen ConOps.
- NextGen implementation and operation requires the cooperation of all three operational departments. Transportation, Commerce, and Defense must commit to support their part of the implementation and operations.
- Research investment may fall short of that needed to implement NextGen operational concepts. To minimize this risk, research investment plans must be narrowly focused to insert research success efficiently into the operational environment.
- Changes in future versions of the NextGen ConOps may yield new, undiscovered requirements.
- The concepts required in the NextGen ConOps are new. There is the risk that agency and organizational inertia to change the existing architecture efficiently and safely to that envisioned in the NextGen ConOps will not be overcome. Specific concerns center on these issues:
  – The integration of weather information into the ATM processes, especially the reliance on automated decision tools that effectively use probabilistic weather information.
  – The ability to update today's Federal Aviation Regulations (FAR) so they can be applied to tomorrow's products. For example, how is the wording of current FARs regarding "known or forecast icing conditions" changed when future icing products contain probabilistic forecasts for icing (e.g., does a 5 percent chance of light icing qualify as "known or forecast icing conditions"?).
  – User education and use. Can users safely and efficiently plan flights using high-resolution, frequently refreshed weather observations, analyses, and forecasts without special applications designed to facilitate this task? Can we convert a range of probabilistic forecasts designed for decision tools into deterministic products that are easier for humans to apply?
  – The smooth integration with the airspace of other countries. For instance, can we anticipate the significant issues that will need to be resolved when NextGen concepts meet Canadian and foreign oceanic airspace?

NextGen's ConOps has been described as "Revolutionary."[7] Integration of high-resolution weather information into aviation operations certainly fits the revolutionary nature of NextGen operations. Identifying the risks of this process is the first step to managing them. The list above will be expanded and refined by the functional analysis team in the next phase.

[7] *Business Case for the Next Generation Air Transportation System v1.0*, Joint Planning and Development Office, August 24, 2007, p. ES-1.

8 VALIDATION

8.1 BACKGROUND

The concept of a 4-D Wx SAS is a key component of the success of NextGen's operational capabilities. However, 4-D Wx SAS weather data content and access to this data is of paramount importance. Weather data content *must* be tied directly to or support operational (aviation) user needs—either via integration into decision-support tools or direct access and use. The data *must* support current ongoing operations and evolve in tandem as user (human or machine) needs change.

Identification and validation of *current* user weather needs has historically been difficult. It is relatively easy to validate *which* weather data/information is of interest in a broad sense (e.g., convection forecasts for traffic-flow routing, current and forecast icing for dispatch and flight planning, current and forecast ceiling and visibility [C&A] for arrival rates, etc.); but validating specific data content (e.g., resolution, accuracy, probability), time frame, integrity, and skill that provides end user value has proved elusive.

Traditional validation methods have included operational user forums, direct user feedback including surveys, weather research interpretations, and commercial initiatives. These methods, although well intentioned, have led to a conglomeration of weather information that can be inconsistent and/or of limited operational value in many cases. In addition, the proliferation of similar information/products from different sources that are derived differently often leads to confusion about which source to trust. This affects collaboration between and among decisionmakers.

Specific limitations in value are due in part to accessibility (e.g., information timeliness and content to general aviation [GA] while in flight) or accessibility and focus (e.g., research products becoming operationally available to decisionmakers). Limitations, however, mainly result from weather data performance characteristics that are not well matched with user-defined constructs and related user performance needs.

These aviation constructs—airspace design and use, rules and regulations, aircraft capabilities, and applications based on technology—are reasonably well understood today. Despite such understanding, user weather needs have been poorly quantified using traditional validation approaches. The reasons for this are beyond the scope of this study. However, the identification and validation of *future* user weather needs using similar approaches will likely prove even *more* difficult because the driving aviation constructs needed to determine them are still under development, not well understood or agreed upon, or in some cases not yet identified or envisioned.

8.2 APPROACH

To ensure that the 4-D Wx SAS contains weather information of most value to aviation decisionmakers, an initial validation of user weather needs was performed from the perspective of the NextGen ConOps and the NextGen Weather ConOps. The validation builds on and aims to be consistent with previously identified user needs as illustrated in various foundational studies,

user responses to survey questions, and feedback from recent user need forums (see Appendices H and J).

The foundational studies selected were authored in large part, if not entirely, by operational aviation users (e.g., dispatchers, pilots, traffic flow managers, air traffic controllers) and thus the influence of research and/or commercial initiatives on the needs is limited. In this regard, technology (i.e., solutions or proposed solutions) or research proposals are not driving the need as tends to traditionally occur. The result is that identified user weather needs are more operationally focused and based on the way that users perceived they would meet mission goals or conduct business. Once the needs are identified in this way, perspectives from the research and commercial world can propose solutions (e.g., requirements) to incrementally if not fully satisfy those needs.

In addition to foundational studies, recent results from Friends and Partners of Aviation Weather (FPAW) forums were used. These operational user/research/commercial forums have consistently provided valuable user insight into operational weather information needs as well as research and commercial programs directly addressing those needs.

Unfortunately, while important for initial 4-D Wx SAS content validation, foundational documents and user need forums only provide insight into current or short-term future weather information needs. As previously mentioned, a more difficult undertaking is the validation of user weather needs in the future (e.g., beyond 2012).

To explore future weather needs, survey questions were designed so that the respondents (i.e., operational decisionmakers) would comment on the “likely” or “potential” operational capabilities they envision in NextGen timeframes. These capabilities were intended to be within the context of future NextGen capabilities such as trajectory-based operations, super-density airspace operations, and so forth. The respondents were also asked to comment on how *appropriate* (e.g., focus, performance) weather information would provide some level of value in achieving these capabilities.

Identifying the operational capability allows appropriate weather information to be framed as a supporting enabler to that capability. The weather content of the 4-D Wx SAS can then support that capability *when* and *if* it becomes operational—and not be driven by “advances” in weather information that are poorly matched (e.g., focus, resolution, skill, timeliness, content characteristics) to the capabilities or ATM functions. Weather need “gap” identification was performed to identify potential information needs as well as functionality needs that the 4-D Wx SAS would contain. These were derived by comparing the “best guess” validated user weather needs (near and far term) with the “Observations” and “Forecast” weather functions as identified in Appendix B.

8.3 DATA AND CONTACTS

Foundational documents or studies used to establish the first-level validated weather needs are listed in Appendix J, References. Three of the studies are dated (more than six years old) but they were all authored by operational decisionmakers with little or no influence from research or

commercial initiatives. A summary of weather need findings from these studies is included, along with the survey questions, in Appendix H.

In addition, several operational user points of contact from industry, FAA, and DOD were identified to participate in a short survey to help validate short-term, as well as longer term weather user needs. Table 8-1 highlights the representative contacts. A more detailed list of contacts and their affiliation can be found in Appendix H.

Table 8-1. Total Survey Contacts and their Affiliation

Affiliation	Number of Contacts
Pilot Community (Parts 91, 121, 135)	10
Pilot or Airline Representatives (ATA, NBAA, AOPA, etc.)	6
Dispatch, AOC, Airline Meteorologists	11
Traffic Flow	3
Air Traffic Control	6
Flight Service	1
Air Traffic Management	2
Flight Standards	4
Space Weather	1
Union Representation	1
Specialty Operations (Helicopter, UAS, Microjets)	3
DOD	20

8.4 SURVEY RESULTS

Sixty-eight (68) surveys were distributed to various operational decisionmakers across the FAA and its affiliates and DOD. In addition, five phone and five one-on-one interviews were conducted. Only seven surveys were returned, and none of them offered much validation information—especially for future weather needs. The collected information represents only about 25 percent of the total respondents, and this number of respondents was not great enough to test for statistical significance. However, the information will serve as the basis for follow-on validation activities.

The first questions of the survey (see Appendix H) were designed to validate how well the NextGen and the Weather ConOps were understood and that the responses were the result of an apparent understanding of the NextGen capabilities. As stated in Section 8.2, these capabilities will serve to drive the weather data content in the 4-D Wx SAS.

Agency as well as industry responses indicated that not everyone has read either or both of the ConOps. Those who had not read it were not able to offer much in the way of envisioned operational capabilities. When either of the ConOps had been read, responses indicated that it was fairly well received. Several *generalized* criticisms (gaps) were obtained from the feedback. These are contained in Appendix K, Recommendations for Next Versions of NextGen Concept of Operations and Weather Concept of Operations.

The last question of the survey was intended to validate the ConOps assertion that some anticipated operational decisions will be driven solely by weather, or that more decisions will become more sensitive to weather.

An example of a detailed set of validated *current* decisions is described in the referenced 2000 draft Air Traffic Services (ATS) Concept of Operations paper, Arrival and Departure Services, and was used as a partial initial baseline. Decisions with a *general* magnitude of perceived delay reduction benefit of Extremely High, Very High, and High are shown in Table 8-2.

Table 8-2. Relative Importance of Weather for Air Traffic Control (ATC) Departure and Arrival Service Decisions (Current)

ATC Decisions for Departure and Arrival Services	Magnitude of Benefit
Improving traffic merging and sequencing during adverse wind conditions at airports that have inadequate capacity during IMC	Extremely High
Recognizing that a runway will remain open as thunderstorms pass	Very High
Anticipating departure transition area (DTA) closure	High
Anticipating arrival transition area (ATA) closure	High
Anticipating re-opening of ATA	High
Landing rather than holding aircraft before airport shuts down	High
Minimizing diversions before airport shutdown	High
Minimizing diversions near airport re-opening	High

Several other ATC decisions have been given a magnitude of benefit of either Moderate or Low (for Departure and Arrival Service decisions), and the reader can refer to the referenced study. Note that these values are generalized, and when clarified, some of the Moderate or Low benefited decisions may become, as a result of improved weather, High or even Very High, depending on the airport. Such variance in value already occurs today. Survey and interview respondents indicated that few, if any, decisions in the NextGen era will be driven solely by weather, but that *in general*, decisions will become even more sensitive to weather, especially at some airports. In NextGen, the decision value of the weather information for potential delay reduction will become more sensitive to weather as driven by specific airport operations.

None of the respondents were able to quantify an expected change in value except to suggest that some (e.g., route changes by En Route controllers) may occur “quicker.” One survey respondent felt that the largest change the aviation community will see with regard to emerging NextGen capabilities are metering and spacing decisions. Another felt that runway/airport efficiency and runway clearance decisions, if improved by some measure because of access to or integration of appropriate weather information, would be major drivers of improved performance.

Some other interview comments that appear to be directly relatable to 4-D Wx SAS content and/or functionality include the need for:

- Trend-type information (especially for GA) to incorporate (manually) into forecasts
  - Plus or minus 1 hour of arrival time for all points along the route (performance)
  - Trend for icing
  - Trend in probability.

It is noted that trend analyses will be performed by end-user applications and not in the 4-D Wx SAS. However, the 4-D Wx SAS will contain weather information storage consistent with user need timeframes.

Quantifications of forecast reliability (how good was the forecast) was also desired by some survey respondents. This need was incorporated into 4-D Wx SAS functionality and defined in the Lexicon.

Other weather need considerations obtained from the survey feedback are important for retention. However, they are either already captured in the 4-D Wx SAS or beyond its scope. These include:

- Moderate to Severe turbulence (continental United States [CONUS])—all turbulence for Alaska
- 24-hour advance forecasts for GA (used as a trigger for buying a commercial ticket versus piloting)
- Augmentation of on-board radar information (tactical only, echoes beyond range) with complementary ground-based radar information (via data link).

One consideration was consistently received from survey respondents: Procedural changes are deemed far more important than modest improvements in weather information. It appears that even the availability of perfect weather information will not improve decisionmaking and/or ATM performance if processes and procedures addressing the use of that information are not modified.

8.5 FPAW RESULTS

The results from the 2006 and 2007 FPAW meetings were reviewed for user weather need identification and validation. Identified needs were considered to have high integrity, because they were provided directly by operational users.

To identify gaps in potential 4-D Wx SAS information content or functionality, a comparison of identified needs was performed against the “Authorized Weather Sources” function of “Observe” and “Forecast” elements as shown in Appendix B. Any gaps identified were incorporated into the recommended 4-D Wx SAS data content or 4-D Wx SAS functionality lists.

To determine *when* (i.e., 2012, 2016, and 2020) a validated weather information gap may be eliminated, derived weather “enablers” in the JPDO IWP were examined. These enablers contain technologies designed to address the gaps along with their expected evolution into operations. This should provide an adequate “first guess” capability/gap elimination/mitigation time frame. It is noted, however, that budget constraints for the enablers were not considered nor are their measures of success clearly identified.

The following FPAW-derived user weather needs were determined to be more appropriate for incorporation by end-user applications:

- Convection growth and decay trends (Note: Additional follow-on action to validate 4-D Wx SAS retains information for appropriate timescales)
- Quantified “acceptable” volcanic ash detection and forecast for penetration (In addition, ensure that 4-D SAS contains quantifications that match end-user application thresholds of interest)

- Pilot reports (PIREPS) from the previous 4 hours for Dispatch
- Forecasts for 36-hour time frames and longer for winds aloft, en route weather, and weather at airports (unmanned aircraft system [UAS]-driven operations).

Ensure the following needs are addressed by end-user applications only, 4-D Wx SAS functionality only, or both:

- High density/domain selectable ceiling and visibility (C&V) observations and corresponding forecasts
- Forecast C&V skill quantification (determine if probabilistic forecasts address the need)
- Observations and forecasts of low-level turbulence and C&V (lowest 5,000 feet) along a flight route/between reporting and forecasting ground-based stations for helicopters and GA interests (Where are the tailored, highly detailed, trend-oriented, and/or probabilistic analyses/interpretations made?).

It is noted that many, but not all above-identified gaps may be mitigated by end-user applications and are not specific to 4-D Wx SAS weather character requirements. However, the weather performance needs of NextGen tools still require further identification and validation to ensure that weather data performance characteristics in the 4-D Wx SAS are complementary. Such performance characteristics will be closely tied to the NextGen capability desired, as well as the application technologies that integrate airspace, weather, and other data.

8.6 WEATHER NEED STUDY COMMENTS

Only three responses were obtained regarding the validation of the summarized user weather needs from the selected studies (Appendix H). These were from direct authors or from participants in one or more studies. Most of the responses were general in nature and will require further validation. These are shown in Appendix H directly after the documented user needs. Response highlights include:

1. The increase of oceanic data, information from data-sparse regions, and additional upper air observations may allow for the potential of reduced separation and increased capacity.
2. Regarding impacts on arrival and departure procedures, the coordination with approach control and en route can be huge. Trying to mitigate the effects of an extended line of weather (e.g., convection), winds, and ice/snow is tremendous on a regional, let alone national, scale.
    a. One-, two-, or four-hour forecast intervals are more important than once in an 8-hour shift.
    b. The area of consideration is valid when it comes to en route areas of responsibility.
    c. Feeding arrival posts or using the right departure gates is critical.
    d. The tower's concern is based only on what is happening at a moment within at most an hour in the future regarding the winds and/or wet or icing-impacted runways. These types of situations can change rapidly. The type of aircraft and its weight are considerations that affect safety.
3. Although the vast majority of stated user needs are still valid, new needs can emerge based on an improved understanding of the way operational decisionmakers need to use weather information.

a. Northwest Airlines and NWS representatives conducted a terminal radar control (TRACON) forecast test at the Minneapolis TRACON. They found that the concept of "highest probability during the hour" of convection and/or lightning (rather than a snapshot in time of the probability) was possibly more valuable for operations. This occurred because changing TRACON traffic flows necessitates much coordination between various decisionmakers (e.g., ATC, ATM, flight dispatchers, and pilots). According to a paper drafted by T. Fahey, et al. (planned for 2008 AMS presentation), it was assumed that "Information based on an estimate of the worst conditions expected during the 1-hour period would be necessary rather than probability of convection at only one instant."
b. This concept would be valid for other TRACONs because the use of the weather information is being driven more by ATM procedures than by the actual precision of the forecast.
c. Given the earlier validation that operational decisions will essentially remain the same (but will become more sensitive to weather information especially at some airports), this proposed *concept* (assuming verification) can remain the same in both the near- as well as in longer-term NextGen time frames. However, the forecast period of interest may be reduced—especially for Super Density Operations (e.g., highest probability within 30 minutes).

9 RECOMMENDED FOLLOW-ON ACTIVITIES

The NextGen Weather Functional Requirements Study Team performed a functional analysis on the NextGen ConOps v2.0 and the NextGen Weather ConOps v1.0. The TOR directed the team to develop functional requirements for NextGen (as delivered through the primary weather interface to operational decisionmakers). Based on the assigned schedule from JPDO leadership, the team was tasked with the development of 4-D Wx SAS functional and limited performance requirements only. It is crucial to the success of NextGen that the JPDO member agencies know all the functions of NextGen, so to effectively implement required capabilities.

The functions associated with the 4-D Wx SAS itself comprise about 5 percent of the functions which must be performed in NextGen. The “Observe” and “Forecast” functions, which were decomposed to a very low level to determine the contents of the 4-D Wx SAS, comprise the majority of the NextGen weather functions. Since this decomposition keyed on information needed directly by the decisionmaker, it did not include the functions associated with the intermediate activities. For example, vorticity and helicity are used to support the development of the convection forecast, but are not used directly by the decisionmaker and so were not included. After the functional analyses to the lowest levels have been completed for all NextGen capabilities, the study team will review this work to determine whether additional weather requirements are needed.

A follow-on team must finalize the draft set of weather functional requirements and develop the 4-D Wx Data Cube performance requirements. After the draft performance requirements have been developed, modeling and simulations must be performed with the participation of a representative set of NextGen decisionmakers to refine the draft performance requirements into the final set of NextGen weather requirements. The development of a quality set of performance requirements will take a minimum of 6 to10 months, assuming at least a 50 percent commitment by all required SMEs. The modeling and simulation activities will take 12 to18 months.

To determine the priority of funding for NextGen capabilities, the development of a model that can simulate the operations as defined in the ConOps is essential. It is not currently known how much weather impact on the NAS can be mitigated. If for an equivalent amount of money (e.g., $10 million) the convective forecast accuracy can be increased by 8 percent, the turbulence forecast accuracy can be increased by 13 percent, or the icing forecast accuracy can be increased by 16 percent, which has the most impact on NAS operations? If the weather forecast was perfect, how much would it improve operations and reduce delays? Until the answers to these questions are known, the decisions of which improvements to fund cannot be determined as the data needed for this decision is unavailable.

Follow-on validation activities will be required to add integrity to the gathered responses. The detailed contacts list in Appendix H will serve as the foundation for these activities. Also, several responses require follow-on work to better understand user needs:

- Combining C&V information with convection attributes was found to be very important to GA. Further validation will be required to quantify more specifically the elements of C&V and convection which the user community desires to be combined. This validation needs to involve the flight deck display.

- A related need that was identified is for high-density/domain-selectable C&V observations and corresponding forecasts. Follow-up activities to further quantify locations and density of observational sites should be performed.
- Other examples are more performance-driven, such as the expressed need for 1- to 2-minute weather updates for TRACON decisionmakers. These performance updates will need additional clarification as to which kinds of weather updates and what level of skill are needed. Convection growth and decay trends require further validation to determine what appropriate timescales of interest are needed for decisionmakers.
- Validation with authors and associated contributors to obtain consensus of weather needs is essential as many identified weather needs did not quantify performance requirements (e.g., 2- to 6-hour TRACON area forecasts do not have components of spatial and temporal accuracy, resolution, and skill). Also, some needs were not included in the 4-D Wx SAS Performance Requirements cited in Section 4 and must be included in the follow-on activity that completes the NextGen weather performance requirements.

The agency representatives who built this requirement set each brought to the group a high-level understanding of the NextGen weather needs. They had differing views of what the 4-D Weather Cube should be, and how their particular agency would handle the complex task of building the cube. DOD, FAA, and NOAA all have 4-D Weather Cube (some call it 4-D database) projects either in development or in limited operation. DOD has the Virtual Joint Meteorological and Oceanographic Database, which provides on-demand automated delivery of comprehensive, timely, relevant, accurate, and consistent environmental information for military operations. The NWS has 4-D type products available on display on the Aviation Digital Display Service (ADDS) Web site (http://adds.aviationweather.gov). Although it is important to leverage the work from these initial 4-D capabilities, it is critical for the success of NextGen that additional work meets the set of specified functional requirements started by this group and further detailed by subsequent study teams. Moreover, the team suggests continued cooperation and coordination between these agencies to produce the 4-D Wx SAS, as well as the entire 4-D Wx Cube.

APPENDIX A. WEATHER INFORMATION CONTENT FOR THE 4-D WX SINGLE AUTHORITATIVE SOURCE (SAS)

Table A-1. "Observe Atmospheric and Space Conditions" Information Elements

2nd Lowest "Broken" Cloud Layer	2nd Lowest "Scattered" Cloud Layer	3-Hour Pressure Tendency
Accumulation of Liquid Precipitation	Accumulation of Snow	Accumulation of Solid Precipitation
Airport Visibility	Airport Wind	Airport Wind Direction
Airport Wind Speed	Airspeed Loss/Gain of Low Level Wind Shear	Airspeed Loss/Gain of Microburst
Altitude (Flight Level) of Thunderstorm Cloud Tops	Altitude of Freezing Level	Altitudes with Low Level Wind Shear
Atmospheric Moisture	Atmospheric Temperature	Barometric Pressure
Beginning Time of Freezing Rain	Beginning Time of Ice Pellets	Beginning Time of Liquid Precipitation
Beginning Time of Microburst	Beginning Time of Snow	Beginning Time of Solid Precipitation
Beginning Time of Squall	Beginning Time of Thunderstorm	Beginning Time of Wind Shear
Cloud Ceiling	Cloud Layer Height	Cloud Type
Compression[1] Winds	Density of Volcanic Ash	Direction of Liquid Precipitation Movement
Direction of Microburst Movement	Direction of Solid Precipitation Movement	Direction of Thunderstorm Movement
Duration of Geomagnetic Storm Activity	Duration of Solar Radiation	Ending Time of Ice Pellets
Ending Time of Liquid Precipitation	Ending Time of Microburst	Ending Time of Snow
Ending Time of Snow Pellets	Ending Time of Squall	Ending Time of Thunderstorm
Ending Time of Wind Shear	Existence of Surface Icing Conditions	Frequency of Inter-Cloud Lightning
Frequency of Intra-Cloud Lightning	Frequency of Cloud-to-Ground Lightning	Funnel Cloud Beginning Time
Funnel Cloud Ending Time	Funnel Cloud Intensity	Funnel Cloud Location
Funnel Cloud Movement Direction	Funnel Cloud Movement Speed	Ground Surface Temperature
Gust Front Location	Gust Front Movement Direction	Gust Front Movement Speed
Highest "Broken" Cloud Layer	Highest "Scattered" Cloud Layer	Ice Pellet Intensity
Intensity of Clear Air Turbulence	Intensity of Convective Induced Turbulence	Inter-Cloud Lightning
Intra-Cloud Lightning	Large Lake Swell Direction	Large Lake Swell Height
Large Lake Wave Direction	Large Lake Wave Height	Layer(s) Where Volcanic Ash Is Most Concentrated
Cloud-to-Ground Lightning	Liquid Precipitation Aloft	Liquid Precipitation Type
Liquid Water Equivalent of Snowfall	Location of Blowing Dust	Location of Blowing Sand
Location of Blowing Snow	Location of Blowing Spray	Location of Drizzle
Location of Dust Storms	Location of Fog	Location of Fog Bank
Location of Fog Patches	Location of Freezing Drizzle	Location of Freezing Drizzle
Location of Freezing Fog	Location of Freezing Rain	Location of Freezing Rain
Location of Frost	Location of Geomagnetic Storm Activity	Location of Hail
Location of Hail Shower	Location of Haze	Location of Ice Crystals
Location of Ice Pellets	Location of In-Flight Icing	Location of Low Drifting Sand
Location of Low Drifting Snow	Location of Low Level Wind Shear	Location of Mesocyclone
Location of Mist	Location of Partial Fog	Location of Rain
Location of Rain Shower(s)	Location of Sandstorm	Location of Shallow Fog
Location of Small Hail	Location of Smoke	Location of Snow

1 Compression Winds—Related to wind change in speed/direction with height over/near airports; vertical wind profile.

Location of Snow Grains	Location of Snow Pellets	Location of Snow Showers
Location of Snow Showers	Location of Squalls	Location of Super-Cooled Liquid Droplets (SLD)
Location of Thunderstorm Decay	Location of Thunderstorm	Location of Virga
Location of Volcanic Ash	Location of Well-Developed Dust/Sand Whirls	Location of Widespread Dust
Lowest "Broken" Cloud Layer	Lowest "Few" Cloud Layer	Lowest "Overcast" Cloud Layers
Lowest "Scattered" Cloud Layer	Magnitude of Solar Radiation Impinging on Atmosphere	Maximum Altitude of Cloud Tops
Mesocyclone Direction of Movement	Mesocyclone Intensity	Mesocyclone Speed of Movement
Minimum Altitude (FL) of TS Cloud Base	Movement Direction of Wind Shear	Ocean Swell Direction
Ocean Swell Height	Ocean Wave Direction	Ocean Wave Height
Onset of Geomagnetic Storm Activity	Overcast Cloud Layer	Peak Wind Direction
Peak Wind Speed	Pressure Change	Pressure Falling Rapidly
Pressure Rising Rapidly	Pressure Tendency	Prevailing Visibility
Rain Intensity	Rain Rate	Rain Shower Intensity
Regions of High Energy (> 100 MeV) of Solar Radiation	Runway Departure Wind Direction	Runway Departure Wind Speed
Runway Mid-Point Wind Direction	Runway Mid-Point Wind Speed	Runway Threshold Wind Direction
Runway Threshold Wind Speed	RVR 10-Minute Average	RVR at Mid-Point
Runway Visual Range (RVR) at Rollout	RVR at Touchdown	Sea Level Pressure
Sea Surface Temperature	Sector Visibility	Size of Largest Hailstone
Sky Cover	Slant Range Visibility for Approach and Departure Corridors	Snowfall Intensity
Snowfall Rate (inches/hour)	Solid Precipitation Type	Speed of Liquid Precipitation Movement
Speed of Microburst Movement	Speed of Thunderstorm Movement	Speed of Wind Shear Movement
Squall Wind Direction	Squall Wind Speed	Station Altimeter Setting
Station Density Altitude	Station Pressure	Surface Dew Point Temperature
Surface Icing Accretion Rate (inches/hour)	Surface Maximum Temperature	Surface Minimum Temperature
Surface Obscurations (to Visibility)	Surface Temperature	Surface Visibility
Thunderstorm Cell Intensity	Thunderstorm Cell Location	Thunderstorm Cloud Top
Thunderstorm Growth Location	Thunderstorm Initiation Location	Thunderstorm Intensity
Time of Onset of Solar Radiation (e.g., Solar Flares, Coronal Mass Ejections)	Time of Peak Wind	Time of Wind Shift
Location of Wind Shift	Time Surface Icing Accretion Began	Time Surface Icing Accretion Ends
Tornado Beginning Time	Tornado Cloud Base Height	Tornado Ending Time
Tornado Intensity	Tornado Location	Tornado Movement Direction
Tornado Movement Speed	Tower Visibility	Type of In-Flight Icing (e.g., Rime, Clear, SLD)
Variable Cloud Ceiling	Variable Prevailing Visibility	Variable Wind Direction
Variable Wind Speed	Volume of Air-Containing Volcanic Ash	Wake Vortex Location at Designated Airports
Water Spout Beginning Time	Water Spout Ending Time	Water Spout Intensity
Water Spout Location	Water Spout Movement Direction	Water Spout Movement Speed
Weather Conditions That Affect Braking Action	Where Snow Is Blowing Over Runways	Wind Direction
Wind Direction for Designated Runways	Wind Gust Direction	Wind Gust Location
Wind Gust Speed	Wind Gust Time	Wind Direction

Wind Speed	Wind Speed for Designated Runways	Wake Vortex (WV) Dissipation at Designated Airports
WV Horizontal Displacement at Designated Airports	WV Vertical Displacement at Designated Airports	

Table A-2. “Forecast Weather” Information Elements

Accumulation of Liquid Precipitation (WP)	Accumulation of Snow (WP)
Airport Surface Temperature (WP)	Airport Visibility (WP)
Airspeed Gain or Loss Due to Microburst (WP)	Airspeed Gain or Loss with Wind Shear (WP)
Altitude of Cloud Layer Bases (WP)	Altitude of Cloud Layer Top (WP)
Areas of Widespread Low Visibility (WP)	Base of Clear Air Turbulence (CAT) (WP)
Base of Convective Induced Turbulence (CIT) (WP)	Base of Volcanic Ash Cloud (WP)
Beginning Time of Liquid Precipitation	Beginning Time of Snow (WP)
Beginning Times of Freezing Precipitation (WP)	Blowing Dust
Blowing Snow at Airport	Blowing Spray at Airport
Ceiling (WP)	Ceilings at Airport (WP)
Cloud Layer Thickness (WP)	Cloud Stratification (Type)
Cloud Types	Direction of Precipitation Movement
Dominant Cloud Layer Base Heights	Drizzle (WP)
Duration of Geomagnetic Storm Activity	Duration of Liquid Stratiform Precipitation (WP)
Duration of Solar Radiation (WP)	Duration of Solid Stratiform Precipitation (WP)
Duration of Stratiform Precipitation (WP)	Duration of Wind Shifts
Ending Time of Liquid Precipitation	Ending Time of Solid Precipitation (WP)
Ending Times of Freezing Precipitation (WP)	Ending Times of Snow (WP)
Flight Level of Cloud Tops (WP)	Fog at Airport (WP)
Freezing Drizzle (WP)	Freezing Level Aloft (WP)
Freezing Rain (WP)	Frost (WP)
Ground Temperature (WP)	Hail (WP)
Hail Size (WP of $\geq$ ½ inch)	Haze at Airport
Ice Accretion Rate (WP)	Ice Crystals (WP)
Ice Pellet Intensity (WP)	Imminent Lightning (within 10 minutes) (WP)
Instrument Flight Rules (IFR) Conditions (WP)	Intensity of CIT (WP)
Intensity of Clear Air Turbulence by Aircraft Type (CAT) (WP)	Intensity of In-Flight Icing Accumulation by Aircraft Type (WP)
Intensity of Solar Radiation (WP)	Intensity of Thunderstorm Cell (WP)
Large Lake Swell Direction (WP)	Large Lake Wave Direction (WP)
Large Lake Wave Heights (WP)	Large Lake Wave Heights (WP)
Liquid Precipitation Aloft	Liquid Precipitation Movement
Liquid Water Equivalent of Snowfall Accumulation (WP)	Location of Ceiling
Location of Clear Air Turbulence (CAT) (WP)	Location of Cloud-to-Ground Lightning (WP)
Location of Convective Induced Turbulence (CIT) (WP)	Location of Freezing Precipitation (WP)
Location of Geomagnetic Storm Activity	Location of Hail (WP)
Location of Ice Pellets (WP)	Location of In-Flight Icing (WP)
Location of Inter-Cloud Lightning (WP)	Location of Intra-Cloud Lightning (WP)
Location of Liquid Precipitation	Location of Mesocyclones (WP)
Location of Operationally Significant Solar Activity (WP)	Location of Stratiform Precipitation
Location of Thunderstorm (WP)	Location of Thunderstorm Cell (WP)
Location of Volcanic Ash Cloud (WP)	Location of Wind Gusts (WP)
Locations of Convective Initiation (WP)	Locations of Thunderstorm Decay (WP)
Locations of Thunderstorm Growth (WP)	Low Clouds (WP) at Airport
Low Clouds at Designated Air Portals	Low Drifting Snow at Airport
Low Level Wind Shear “at” or “in Vicinity” of Designated Air Portals (WP)	Maximum Altitude of Cloud Tops (WP)
Maximum Surface Temperature (WP)	Mesocyclone Movement Direction (WP)
Mesocyclone Movement Speed (WP)	Microburst “at” or “in Vicinity” of Designated Air Portals (WP)
Movement of Volcanic Ash Cloud (WP)	Occurrence of Moderate or Greater Rain Showers (WP)

Occurrence of Variable Winds (WP)	Occurrence of Wind Shifts (WP)
Ocean Swell Direction (WP)	Ocean Swell Heights (WP)
Ocean Wave Direction (WP)	Ocean Wave Heights (WP)
Onset of Geomagnetic Storm Activity	Onset of Solar Radiation (WP)
Onset of Stratiform Precipitation (WP)	Peak Wind Direction
Peak Wind Speed	Period of Solar Radiation Maximum Exposure (WP)
Position of Jet Stream	Rain Intensity (WP)
Rain Intensity (WP)	Region(s) of SLD (WP)
Regions (Space, Polar, High-Latitude, and Mid-Latitude) Susceptible to High Energy (> 100MeV) Solar Radiation	Regions of High Energy (> 10 MeV) of solar radiation
Relative Humidity	Runway Winds (WP)
RVR (10-minute average) (WP)	Sea Surface Temperature (WP)
Sky Cover (WP)	Slant Range Visibility at Designated Airports for Approach and Departure Corridors (WP)
Smoke	Smoke at Airport (WP)
Snow (WP)	Snow Intensity (WP)
Snow Pellets (WP)	Snow Shower (WP)
Snowfall Accumulation (WP)	Snowfall Rate (WP)
Solid Stratiform Precipitation	Surface Dew Point Temperature (WP)
Surface Icing Accumulation (WP)	Surface Obscurations < 6,000' for Areas Beyond Airports
Surface Wind Direction (WP)	Surface Wind Speed (WP)
Temperature	Terminal IFR Conditions (WP)
Thunderstorm Movement Direction (WP)	Thunderstorm Movement Speed (WP)
Thunderstorm Precipitation Accumulation (WP)	Thunderstorms (WP)
Top of Clear Air Turbulence (CAT) (WP)	Top of Convective Induced Turbulence (CIT) (WP)
Top of Surface Obscuration at Designated Airports (WP)	Top of Volcanic Ash Cloud (WP)
Type of In-Flight Icing (WP)	Variable Wind Direction (WP)
Variable Wind Speed (WP)	Vertical Wind Profile up to 225,000 ft for Spaceports
Volcanic Ash Dispersion (WP)	Wake Vortex (WV) at Designated Airports
Widespread Low Visibility (WP)	Wind Compression Profile to Top of Terminal at Designated Airports
Wind Direction (WP)	Wind Direction at Runway Departure (WP)
Wind Direction at Runway Threshold (WP)	Wind Direction at Runway Threshold (WP)
Wind Gust Direction (WP)	Wind Gust Speed (WP)
Wind Shift (WP)	Wind Shift Duration
Wind Speed (WP)	Wind Speed at Runway Departure (WP)
WV Displacement at Designated Airports (WP)	WV Dissipation at Designated Airports (WP)

APPENDIX B. FUNCTIONAL HIERARCHY DIAGRAMS

As was mentioned in Section 4, the Observe and Forecast Subteams performed a detailed decomposition of the functions of “Observe Atmospheric and Space Conditions” and “Forecast Weather” to determine the data contents of the 4-D Wx SAS. This Appendix provides several diagrams (Figures B-1, B-2, and B-3), which relate pictorially the functional hierarchy of how low-level Weather Services (or functions) of Observe Weather and Forecast Weather are tied to the higher level Enterprise Services (or functions). To incorporate functions for Space Weather, Observe Weather becomes Observe Atmospheric and Space Conditions. Lastly, a hierarchical numbering scheme is used to depict a “parent-child” relationship of the subfunction ‘child’ under its function “parent.”

Figure B-1. Functional Hierarchy for Enterprise Services

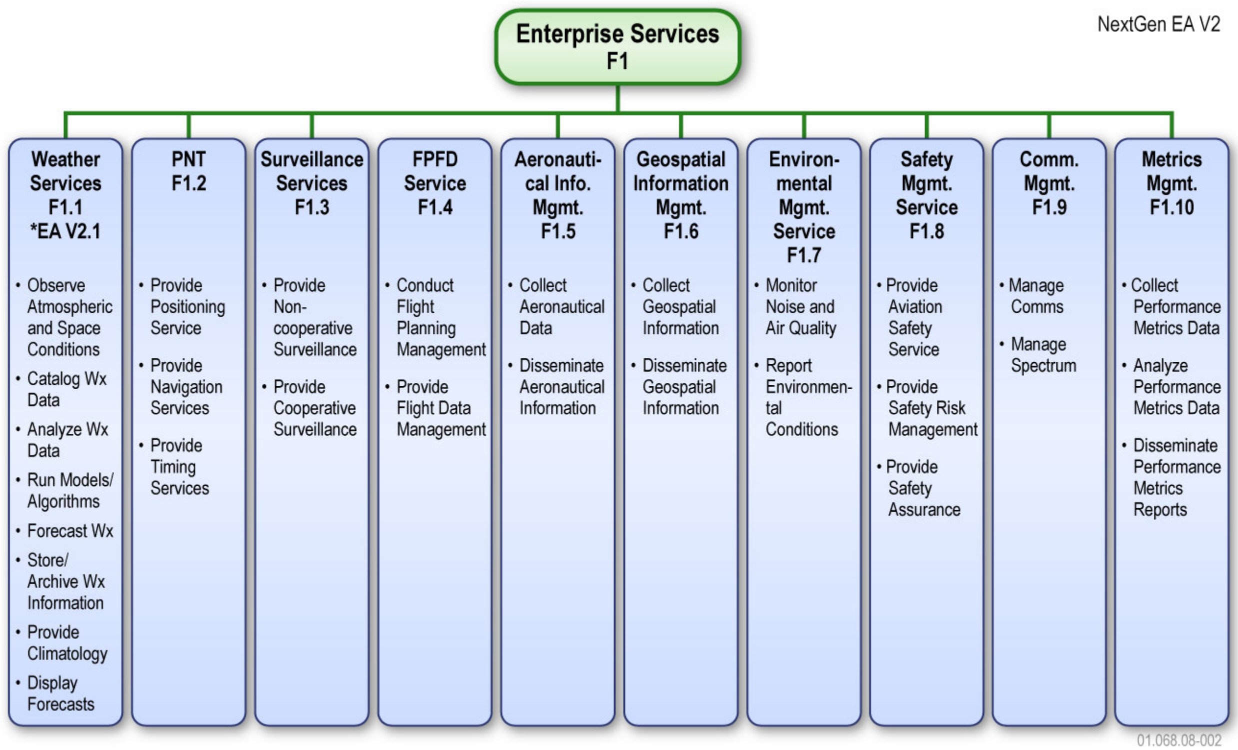


Figure B-2. Functional Hierarchy for Observe Atmospheric and Space Conditions

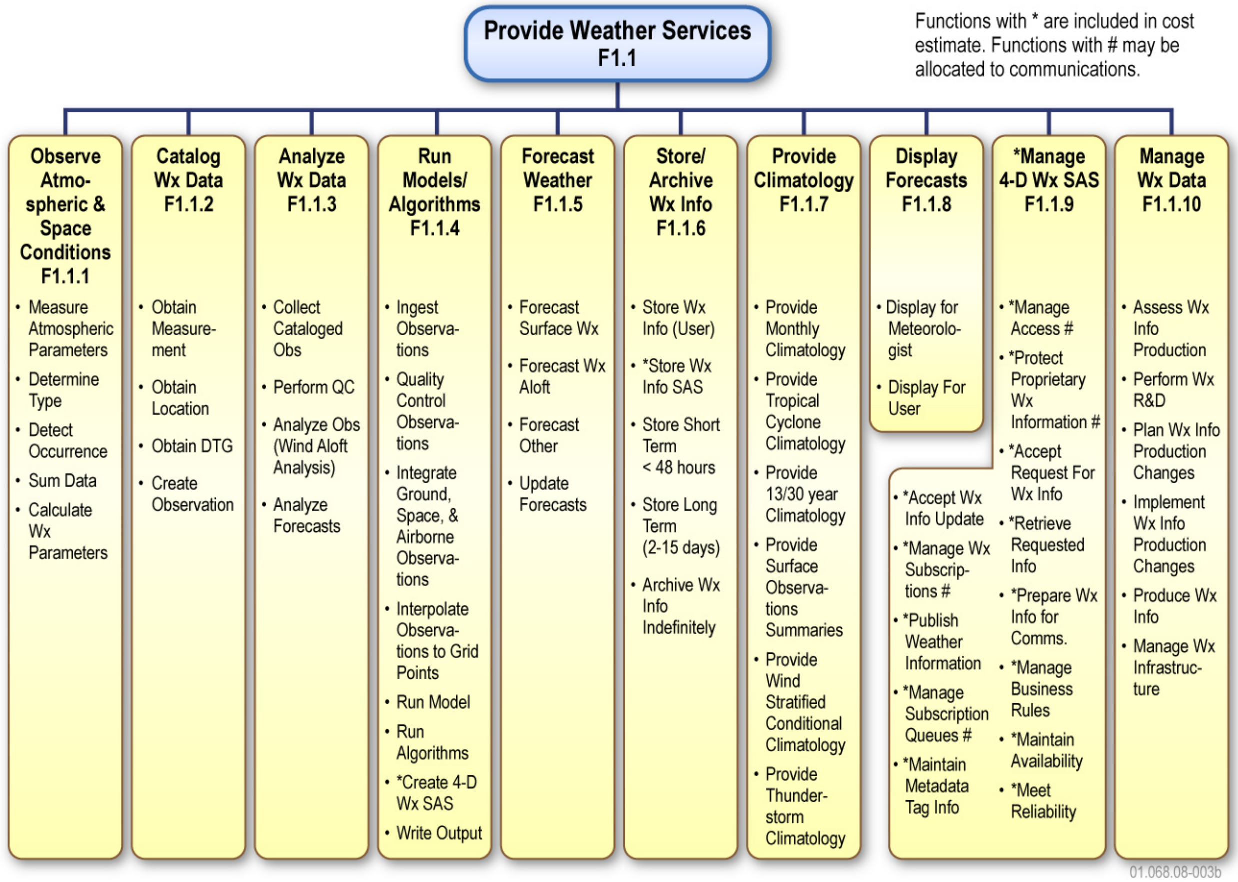
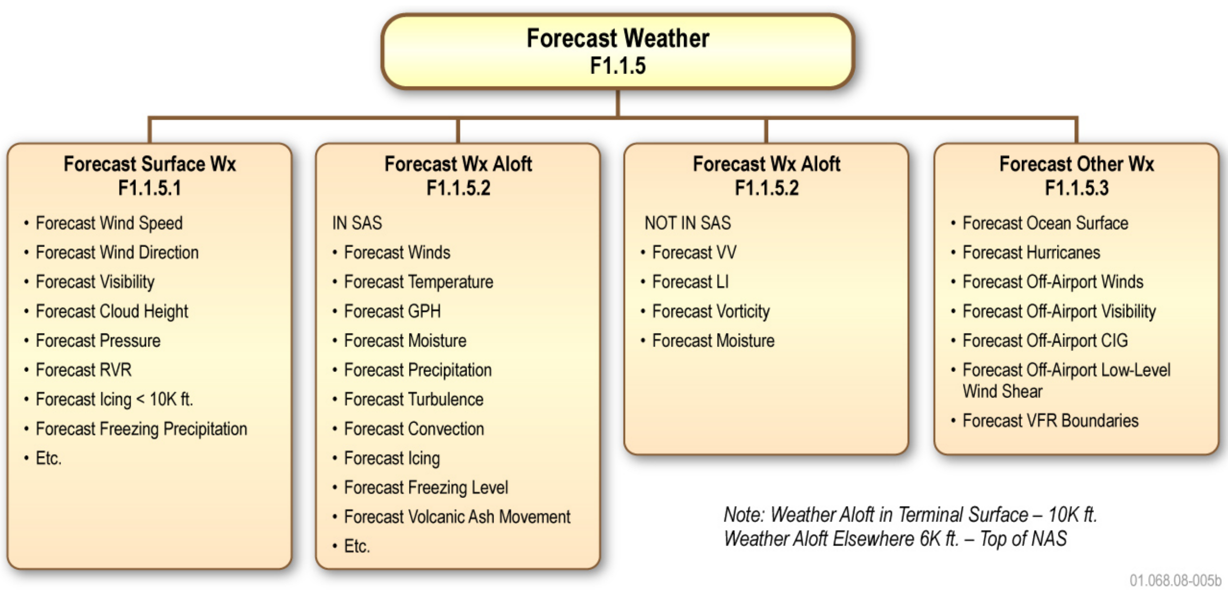


Figure B-3. Functional Hierarchy for Forecast Weather



The functional decomposition starts at the highest level, that of Enterprise Services F1, as shown in Figure B-1. From the left side of Figure B-1, under Weather Services F1.1, one can see the

origin of the Observe and Forecast weather functions. Figures B-2 and B-3 provide additional information about the sub-functions under Observe Atmospheric and Space Conditions and Forecast Weather functions, respectively. In addition, as Enterprise Services (or functions) they support various services under Enterprise Services that require weather data/information, including Surveillance Services and Flight Planning Services.

The symbols in the following list indicate the traceability of the Observe and Forecast functions to the Next Generation Air Transportation System Concept of Operations (NextGen ConOps) v2.0 subfunctions:

Provide weather information to support:	Symbol to use for traceability:
Air Traffic Operations	#
Traffic Management (or Capacity) Operations	*
Flight Community (Operators)	^
Terminal Airspace Configuration	~
Ground Operations	%

Items residing within the 4-D Wx Cube, but not in the 4-D Wx SAS, have a "+" symbol immediately after the function. Note that some of the Observe and Forecast functions listed may not exist by the time that NextGen is implemented, or may have changed significantly to meet the 4-D Wx SAS requirements per the list below. For example, at present, ceiling and visibility are essential to air traffic management (ATM), but with significant research and development (R&D) a capability may be developed (e.g., "synthetic vision") to allow these functions to be removed. As R&D progresses and as the NextGen weather needs become more detailed, we anticipate (and encourage) additional modification to the functional hierarchy. Although sometimes lengthy team discussions were held concerning the functions described below, it is important to note, when reviewing the list below, that these discussions often led to the realization that there was simply not enough information available for a more exact definition of the function.

F.1 Enterprise Services

F1.1 Provide Weather Services—Level at which 4-D Wx SAS resides (Section 4)

F1.1.1 Observe[1] Atmospheric and Space Conditions

Note: For brevity, the leading "F1.1" *in the numbering scheme is eliminated hereafter. For example,* "F1.1.1 Observe Atmosphere and Space Conditions" *becomes* "**l Observe Atmosphere and Space Conditions**":

1 Observe Atmosphere and Space Conditions

1.1 Observe Weather +

1.1.1 Observe Present Surface Weather ^ # * ~ %

1.1.1.1 Observe Surface Liquid Precipitation + ^ # * ~

[1] Observe = To evaluate or measure, by human or automated means, one or more meteorological elements (e.g., temperature, wind speed/direction, visibility, precipitation) that describe the state of the atmosphere either at Earth's surface or aloft.

1.1.1.1.1 Determine Liquid Precipitation Type	^	#		
1.1.1.1.1.1 Determine Location of Drizzle	^	#		
1.1.1.1.1.1.1 Determine[2] Horizontal Extent of Drizzle	^	#	*	
1.1.1.1.1.1.2 Determine Vertical Extent of Drizzle	^	#		
1.1.1.1.1.2 Determine Location of Rain	^	#		
1.1.1.1.1.2.1 Determine Horizontal Extent of Rain	^	#	*	
1.1.1.1.1.3 Determine Location of Rain Shower(s)	^	#		
1.1.1.1.1.4 Measure[3] Accumulation of Liquid Precipitation	^	#		
1.1.1.1.1.5 Determine Movement Direction of Liquid Precipitation	^	#		
1.1.1.1.1.6 Determine Movement Speed of Liquid Precipitation	^	#		
1.1.1.1.1.7 Calculate Rain Fall Intensity	^	#		
1.1.1.1.1.7.1 Calculate Rain Fall Rate (inches/hour)	^	#	*	
1.1.1.1.1.7.1.1 Determine Beginning Time of Liquid Precipitation	^	#		
1.1.1.1.1.7.1.2 Determine Ending Time of Liquid Precipitation	^	#		
1.1.1.2 Observe Surface Solid Precipitation +				
1.1.1.2.1 Determine Solid Precipitation Type	^	#		
1.1.1.2.1.1 Determine Location of Hail	^	#		%
1.1.1.2.1.1.1 Determine Horizontal Extent of Hail	^	#	*	%
1.1.1.2.1.1.2 Estimate Size of Largest Hailstone (inches)	^	#		
1.1.1.2.1.1.3 Determine Location of Hail Shower	^	#		
1.1.1.2.1.2 Determine Location of Snow	^	#		
1.1.1.2.1.2.1 Determine Horizontal Extent of Snow	^	#	*	%
1.1.1.2.1.2.2 Measure Snowfall Accumulation	^	#	*	%
1.1.1.2.1.2.3 Determine Location of Snow Showers	^	#	*	
1.1.1.2.1.2.4 Measure Snowfall Rate (inches/hour)	^	#	*	%
1.1.1.2.1.2.4.1 Determine Snowfall Beginning Time	^	#	*	%
1.1.1.2.1.2.4.2 Determine Snowfall Ending Time	^	#	*	%
1.1.1.2.1.2.5 Calculate Liquid Water Equivalent of Snowfall (inches/hour)	^	#		%
1.1.1.2.1.3 Observe Ice Crystals +	^	#		
1.1.1.2.1.3.1 Determine Location of Ice Crystals	^	#		
1.1.1.2.1.4 Determine Location of Ice Pellets	^	#		
1.1.1.2.1.4.1 Determine Location of Ice Pellets	^	#		
1.1.1.2.1.4.2 Determine Horizontal Extent of Ice Pellet Showers	^	#		
1.1.1.2.1.4.3 Measure Ice Pellet Intensity	^	#		
1.1.1.2.1.4.4 Determine Beginning Time of Ice Pellets	^	#	*	
1.1.1.2.1.4.5 Determine Ending Time of Ice Pellets	^	#	*	
1.1.1.2.1.5 Determine Location of Snow Grains	^	#		
1.1.1.2.1.6 Determine Location of Blowing Snow	^	#		

[2] Determine = To establish or ascertain definitely, as after consideration, investigation, or calculation.
[3] Measure = To ascertain the extent, dimensions, quantity, capacity, and so on, by comparison with a standard.

1.1.1.2.1.6.1 Determine Where Snow Is Blowing Over Runways[4]	^ # * ~ %
1.1.1.2.1.7 Determine Location of Low Drifting Snow	^ # * ~ %
1.1.1.2.1.8 Determine Location of Small Hail	^ #
1.1.1.2.1.9 Determine Location of Snow Pellets	^ #
1.1.1.2.1.9.1 Determine Beginning Time of Snow Pellets	^ #
1.1.1.2.1.9.2 Determine Ending Time of Snow Pellets	^ #
1.1.1.3 Observe Surface Freezing Precipitation +	^ # * ~
1.1.1.3.1 Determine Location of Freezing Rain	^ # * ~ %
1.1.1.3.1.1 Determine Horizontal Extent of Freezing Rain	^ # * ~ %
1.1.1.3.2 Determine Location of Freezing Drizzle	^ # * ~ %
1.1.1.3.2.1 Determine Horizontal Extent of Freezing Drizzle	^ # * ~ %
1.1.1.3.3 Determine Existence of Surface Icing Conditions	^ # * ~ %
1.1.1.3.3.1 Determine Time When Surface Icing Accretion Began	^ # * ~ %
1.1.1.3.3.2 Measure Intensity of Freezing Precipitation	^ # ~ %
1.1.1.3.3.3 Determine Surface Icing Accretion Rate (inches/hour)	^ # * ~ %
1.1.1.3.3.3.1 Determine Beginning Time of Freezing Precipitation	^ # * ~ %
1.1.1.3.3.3.2 Determine Ending Time of Freezing Precipitation	^ # * ~ %
1.1.1.4 Observe Surface Obscurations (to Visibility)	^ # *
1.1.1.4.1 Determine Location of Haze	^ # *
1.1.1.4.2 Determine Location of Smoke	^ # *
1.1.1.4.3 Determine Location of Mist	^ # *
1.1.1.4.4 Determine Location of Fog	^ # * ~
1.1.1.4.4.1 Determine Location of Shallow Fog	^ # *
1.1.1.4.4.2 Determine Location of Partial Fog	^ # *
1.1.1.4.4.3 Determine Location of Fog Patches	^ # *
1.1.1.4.4.4 Determine Location of Freezing Fog	^ # *
1.1.1.4.5 Determine Location of Blowing Spray	^ #
1.1.1.4.6 Determine Location of Blowing Sand	^ # * ~ %
1.1.1.4.6.1 Determine Location of Low Drifting Sand	^ # ~ %
1.1.1.4.7 Determine Location of Blowing Snow	^ # *
1.1.1.4.8 Determine Location of Widespread Dust	^ # *
1.1.1.4.9 Observe Volcanic Ash	^ # * ~
1.1.1.4.9.1 Determine Horizontal Extent of Volcanic Ash	^ # * ~ %
1.1.1.5 Observe Other Surface Weather +	
1.1.1.5.1 Observe Thunderstorms	^ # * ~
1.1.1.5.1.1 Measure Direction of Thunderstorm Movement	^ # * ~
1.1.1.5.1.2 Measure Speed of Thunderstorm Movement	^ # *
1.1.1.5.1.3 Determine Thunderstorm Intensity	^ # * ~
1.1.1.5.1.4 Determine Horizontal Extent of Thunderstorm	^ # * ~

[4] But not snowing at point of observation.

1.1.1.5.1.5	Determine Vertical Extent of Thunderstorm	^ # *
1.1.1.5.1.6	Measure Thunderstorm Cell Intensity	^ # * ~
1.1.1.5.1.7	Determine Thunderstorm Cell Location	^ # * ~
1.1.1.5.1.8	Determine Thunderstorm Initiation Location	^ # *
1.1.1.5.1.9	Determine Thunderstorm Growth Location	^ # *
1.1.1.5.1.10	Determine Location of Thunderstorm Decay	^ # *
1.1.1.5.1.11	Determine Beginning Time of Thunderstorms	^ # *
1.1.1.5.1.12	Determine Ending Time of Thunderstorms	^ # *
1.1.1.5.2	Observe Mesocyclone +	
1.1.1.5.2.1	Determine Location of Mesocyclone	^ # *
1.1.1.5.2.2	Measure Mesocyclone Speed of Movement	^ # *
1.1.1.5.2.3	Measure Mesocyclone Direction of Movement	^ # *
1.1.1.5.2.4	Measure Mesocyclone Intensity	^ # *
1.1.1.5.3	Observe Gust Fronts +	
1.1.1.5.3.1	Determine Gust Front Location	# *
1.1.1.5.3.2	Measure Gust Front Movement Direction	# *
1.1.1.5.3.3	Measure Gust Front Movement Speed	# *
1.1.1.5.4	Observe Cloud-to-Ground Lightning +	
1.1.1.5.4.1	Measure Frequency of Cloud-to-Ground Lightning	^ # * %
1.1.1.5.5	Observe Wind Shear/Microburst +	
1.1.1.5.5.1	Determine Location of Low-Level Wind Shear	^ #
1.1.1.5.5.2	Determine Vertical Extent of Low-Level Wind Shear	^ #
1.1.1.5.5.3	Measure Airspeed Loss/Gain of Low-Level Wind Shear	^ #
1.1.1.5.5.4	Measure Movement Direction of Wind Shear/Microbursts	^ # * ~
1.1.1.5.5.5	Measure Movement Speed of Wind Shear/Microbursts	^ # * ~
1.1.1.5.5.6	Determine Beginning Time of Wind Shear/Microburst	^ # *
1.1.1.5.5.7	Determine Ending Time of Wind Shear/Microburst	^ # *
1.1.1.5.6	Observe Squalls[5] +	^ # * ~
1.1.1.5.6.1	Determine Location of Squalls	^ # * ~
1.1.1.5.6.2	Measure Squall Wind speed	^ # * ~
1.1.1.5.6.3	Measure Squall Wind Direction	^ # * ~
1.1.1.5.6.4	Determine Beginning Time of Squall	^ # * ~
1.1.1.5.6.5	Determine Ending Time of Squall	^ # * ~
1.1.1.5.7	Observe Tornadic Activity +	^ # * ~
1.1.1.5.7.1	Determine Funnel Cloud Location	^ # * ~ %
1.1.1.5.7.1.1	Measure Funnel Cloud Movement Direction	^ # * ~ %
1.1.1.5.7.1.2	Measure Funnel Cloud Movement Speed	^ # * ~
1.1.1.5.7.1.3	Measure Funnel Cloud Intensity	^ # * ~

[5] Squall = In an observing practice in the United States, a squall would be reported only if a wind speed of 16 knots or higher were sustained for at least 2 minutes (distinguishing it from a gust, with a duration of seconds).

1.1.1.5.7.1.4	Determine Funnel Cloud Beginning Time	^ # * ~
1.1.1.5.7.1.5	Determine Funnel Cloud Ending Time	^ # * ~
1.1.1.5.7.2	Determine Tornado Location	^ # * ~ %
1.1.1.5.7.2.1	Measure Tornado Movement Direction	^ # * ~ %
1.1.1.5.7.2.2	Measure Tornado Movement Speed	^ # ~
1.1.1.5.7.2.3	Measure Tornado Intensity (F #)	^ # * ~
1.1.1.5.7.2.4	Determine Tornado Cloud Base Height	^ # *
1.1.1.5.7.2.5	Determine Tornado Beginning Time	^ # * ~
1.1.1.5.7.2.6	Determine Tornado Ending Time	^ # * ~
1.1.1.5.7.3	Determine Water Spout Location	^ # * ~ %
1.1.1.5.7.3.1	Measure Water Spout Movement Direction	^ # *
1.1.1.5.7.3.2	Measure Water Spout Movement Speed	^ # *
1.1.1.5.7.3.3	Determine Water Spout Intensity	^ # * ~
1.1.1.5.7.3.4	Determine Water Spout Beginning Time	^ # * ~
1.1.1.5.7.3.5	Determine Water Spout Ending Time	^ # * ~
1.1.1.5.8	Observe Wake Vortex (WV) at Designated Airports +	^ # * ~
1.1.1.5.8.1	Determine Wake Vortex Location	^ # * ~
1.1.1.5.8.2	Determine WV Horizontal Displacement at Designated Airports	^ # * ~
1.1.1.5.8.3	Determine WV Vertical Displacement at Designated Airports	^ # * ~
1.1.1.5.8.4	Determine WV Dissipation at Designated Airports	^ # *
1.1.1.5.9	Observe Well-Developed[6] Dust/Sand Whirls +	
1.1.1.5.9.1	Determine Location of Well-Developed Dust/Sand Whirls	^ # ~
1.1.1.5.10	Determine Location of Sandstorms	^ # * ~
1.1.1.5.11	Determine Location of Dust storms	^ # * ~
1.1.1.5.12	Determine Location of Fog Banks	^ # * ~
1.1.1.5.13	Observe Frost +	^
1.1.1.5.13.1	Determine Horizontal Extent of Frost	^ %
1.1.1.5.14	Observe Weather Conditions that Contribute to Braking Action	^ #
1.1.1.6	**Observe Wind +**	^ # *
1.1.1.6.1	Measure Wind Direction	^ # *
1.1.1.6.2	Measure Wind speed	^ # *
1.1.1.6.2.1	Measure Wind Direction for Designated Runways	^ # * ~
1.1.1.6.2.2	Measure Wind Speed for Designated Runways	^ # * ~
1.1.1.6.2.3	Measure Variable Wind Speed	^ # ~
1.1.1.6.2.4	Measure Variable Wind Direction	^ # ~
1.1.1.6.3	Determine Occurrence of Wind Gusts	^ # ~
1.1.1.6.3.1	Measure Wind Gust Direction	^ # ~
1.1.1.6.3.2	Measure Wind Gust Speed	^ # ~

6 Well-developed dust/sand whirls = Ensemble of particles of dust or sand, sometimes accompanied by small litter, raised from the ground in the form of a whirling column of varying height with a small diameter and approximately a vertical axis.

1.1.1.6.3.3	Determine Time of Wind Gust	^	#		
1.1.1.6.4	Determine Airport Wind	^	#		~
1.1.1.6.4.1	Measure Airport Wind Direction	^	#		~
1.1.1.6.4.2	Measure Airport Wind Speed	^	#		~
1.1.1.6.5	Calculate Wind Shift	^	#	*	~
1.1.1.6.5.1	Calculate Time of Wind Shift	^	#	*	~
1.1.1.6.6	Determine Occurrence of Peak Wind	^	#		
1.1.1.6.6.1	Measure Peak Wind Speed	^	#		
1.1.1.6.6.2	Measure Peak Wind Direction	^	#		
1.1.1.6.6.3	Determine Time of Peak Wind	^	#		
1.1.1.6.7	Determine Calm Wind	^	#		
1.1.1.6.8	Determine Runway Winds	^		*	~
1.1.1.6.8.1	Measure Runway Threshold Wind Direction	^	#	*	~
1.1.1.6.8.2	Measure Runway Threshold Wind Speed	^	#	*	~
1.1.1.6.8.3	Measure Runway Mid-point Wind Direction	^	#		~
1.1.1.6.8.4	Measure Runway Mid-point Wind Speed	^	#		~
1.1.1.6.8.5	Measure Runway Departure Wind Direction	^	#	*	~
1.1.1.6.8.6	Measure Runway Departure Wind Speed	^	#	*	~
1.1.1.7	**Observe Surface Visibility +**	^	#	*	~
1.1.1.7.1	Measure Surface Visibility	^	#	*	~
1.1.1.7.2	Measure Tower Visibility	^	#	*	~
1.1.1.7.3	Measure Airport Visibility	^	#	*	~
1.1.1.7.4	Measure Prevailing Visibility	^	#	*	~
1.1.1.7.4.1	Measure Variable Prevailing Visibility	^	#	*	
1.1.1.7.5	Measure Sector Visibility	^	#	*	
1.1.1.8	**Determine RVR**	^	#	*	~
1.1.1.8.1	Measure RVR at Touchdown	^	#	*	~
1.1.1.8.2	Measure RVR at Mid-point	^	#		~
1.1.1.8.3	Measure RVR at Rollout	^	#		~
1.1.1.8.4	Calculate RVR 10-Minute Average[7]	^	#	*	
1.1.1.9	**Observe Pressure Parameters +**	^	#		
1.1.1.9.1	Observe Barometric Pressure	^	#		
1.1.1.9.2	Calculate Sea Level Pressure	^	#		
1.1.1.9.3	Calculate Station Pressure	^	#		~
1.1.1.9.4	Calculate Pressure Change	^	#		
1.1.1.9.5	Calculate Pressure Tendency	^	#		
1.1.1.9.5.1	Determine Pressure Rising Rapidly (≥ 0.06 "/ hour)	^	#		
1.1.1.9.5.2	Determine Pressure Falling Rapidly (≥ 0.06 "/ hour)	^	#		

7 RVR 10-minute average—For long-line distribution (e.g., International Civil Aviation Organization [ICAO]) and dispatch planning.

1.1.1.9.5.3 Calculate 3-Hour Pressure Tendency	^ #
1.1.1.9.6 Calculate Station Altimeter Setting	^ # ~
1.1.1.9.7 Calculate Station Density Altitude	^ # ~ %
1.1.1.10 Observe Sky Conditions +	^ # *
1.1.1.10.1 Determine Sky Cover	^ # * ~
1.1.1.10.2 Measure Each Layer Height	^ # * ~
1.1.1.10.2.1 Determine Lowest “Few” Layer	^ #
1.1.1.10.2.2 Determine Lowest “Broken” Layer	^ # * ~
1.1.1.10.2.3 Determine “Overcast” Layer	^ # * ~
1.1.1.10.2.4 Determine Lowest “Scattered” Layers	^ #
1.1.1.10.2.5 Determine 2nd Lowest “Scattered” Layer	^ # *
1.1.1.10.2.6 Determine 2nd Lowest “Broken” Layer	^ #
1.1.1.10.2.7 Determine Highest “Broken” Layer	^ #
1.1.1.10.2.8 Determine Highest “Scattered” Layer	^ #
1.1.1.10.3 Determine Cloud Ceiling	^ # * ~
1.1.1.10.3.1 Measure Lowest Cloud Ceiling	^ # * ~
1.1.1.10.3.2 Measure Variable Cloud Ceiling	^ #
1.1.1.10.4 Determine Cloud Type	^ # *
1.1.1.10.5 Determine Maximum Altitude of Cloud Tops	^ # *
1.1.1.11 Observe Airport Surface Temperature +	
1.1.1.11.1 Measure Surface Temperature	^ #
1.1.1.11.1.1 Determine Surface Maximum Temperature	^ # %
1.1.1.11.1.2 Measure Surface Dewpoint Temperature	^ #
1.1.1.11.1.3 Determine Surface Minimum Temperature	^ #
1.1.1.11.2 Measure Runway Surface Temperature	^ #
1.1.1.12 Observe Ocean Surface Conditions +	^ #
1.1.1.12.1 Determine Ocean Wave Height (feet)	^ #
1.1.1.12.2 Determine Ocean Swell Height (feet)	^ #
1.1.1.12.3 Determine Ocean Wave Direction	^ #
1.1.1.12.4 Determine Ocean Swell Direction	^ #
1.1.1.13 Observe Large Lake[8] Surface Conditions +	^
1.1.1.13.1 Determine Large Lake Wave and Swell Height	^ #
1.1.1.13.2 Determine Large Lake Wave and Swell Direction	^ #
1.1.2 Observe Weather Aloft[9] +	^ # *
1.1.2.1 Observe Winds Aloft	^ # ~
1.1.2.1.1 Measure Wind Direction	^ # ~
1.1.2.1.2 Measure Wind Speed	^ # ~
1.1.2.1.3 Determine Compression[10] Winds	^ # ~

[8] Large Lake = Large body of water with sufficient fetch to generate appreciable wave/swell height.
[9] Aloft = Over airports above 10,000 feet; elsewhere, above 6,000 feet (both up to 100 kft).

1.1.2.2	**Observe Obscurations (to Visibility) Aloft +**	^ #
1.1.2.2.1	Determine Slant Range Visibility in Statute Miles for Approach/Departure Corridors at Designated Airports	^ # *
1.1.2.2.2	Determine Location of Smoke Aloft	^ # *
1.1.2.2.3	Determine Location of Blowing Dust Aloft	^ # *
1.1.2.3	**Observe Temperature Aloft +**	^
1.1.2.3.1	Measure Atmospheric Temperature	^
1.1.2.3.2	Measure Atmospheric Moisture to Top of the NAS	^
1.1.2.4	**Observe Precipitation Aloft +**	^ #
1.1.2.4.1	Observe Liquid Precipitation	^ #
1.1.2.4.1.1	Determine Horizontal Extent of Rain	^ #
1.1.2.4.1.2	Determine Vertical Extent (FL) of Rain	^ #
1.1.2.4.1.3	Measure Rain Intensity	^ # *
1.1.2.4.1.4	Determine Horizontal Extent of Drizzle	^ #
1.1.2.4.1.5	Determine Vertical Extent (FL) of Drizzle	^ #
1.1.2.4.1.6	Determine Location of Virga	^
1.1.2.4.2	Observe Solid Precipitation Aloft +	
1.1.2.4.2.1	Determine Horizontal Extent of Hail	^ # *
1.1.2.4.2.2	Determine Vertical Extent (FL) of Hail	^ # *
1.1.2.4.2.3	Measure Hail Intensity	^ # *
1.1.2.4.2.4	Determine Location of Snow Pellets	^ # *
1.1.2.4.2.5	Determine Location of Snow	^ #
1.1.2.4.2.6	Determine Horizontal Extent of Snow	^ #
1.1.2.4.2.7	Determine Vertical Extent (FL) of Snow	^ #
1.1.2.4.2.8	Measure Snowfall Intensity	^ #
1.1.2.4.2.9	Determine Horizontal Extent of Ice Pellets	^ #
1.1.2.4.2.10	Measure Ice Pellet Intensity	^ #
1.1.2.4.2.11	Determine Horizontal Extent of Ice Crystals	^
1.1.2.4.2.12	Determine Vertical Extent (FL) of Ice Crystals	^
1.1.2.4.3	Observe Freezing Precipitation Aloft +	
1.1.2.4.3.1	Determine Horizontal Extent of Freezing Rain	^ # * ~
1.1.2.4.3.2	Determine Vertical Extent (FL) of Freezing Drizzle	^ # * ~
1.1.2.4.3.3	Determine Altitude of Freezing Level	^ #
1.1.2.4.3.3.1	Determine Horizontal Extent of Supercooled Liquid Droplets	^ # *
1.1.2.4.3.3.2	Determine Vertical Extent (FL) of Supercooled Liquid Droplets	^ # *
1.1.2.5	**Observe Other Weather Aloft +**	
1.1.2.5.1	Observe Volcanic Ash Plume +	
1.1.2.5.1.1	Determine Volume of Air Containing Volcanic Ash (FAA Order)	^ # *

[10] Compression Winds = Related to wind change in speed/direction with height over/near airports; vertical wind profile.

1.1.2.5.1.2 Measure Density of Volcanic Ash ^ # *
1.1.2.5.1.3 Determine Layer(s) Where Volcanic Ash Is Most Concentrated (FAA Order) ^ # *
1.1.2.5.2 Determine Altitude (FL) of TS Cloud Tops (Above Echo Tops) ^ # *
1.1.2.5.3 Determine Minimum Altitude (FL) of TS Cloud Bases ^ # * ~
1.1.2.5.4 Observe In-Flight Icing + ^ # * ~
1.1.2.5.4.1 Determine Horizontal Extent of In-flight Icing ^ # * ~
1.1.2.5.4.2 Determine Vertical Extent of In-flight Icing ^ # ~
1.1.2.5.4.3 Determine Type of In-flight Icing (i.e., Rime, Clear, SLD) ^ # ~
1.1.2.5.5 Determine 3-D Extent of Turbulence ^ # * ~
1.1.2.5.5.1 Measure Intensity of Turbulence ^ # * ~
1.1.2.5.6 Observe All Types of Cloud Lightning ^ # * ~
1.1.2.5.7 Observe Space Wx Parameters + ^ #
1.1.2.5.7.1 Observe Solar Radiation Activity (e.g., Solar Flares, Coronal Mass Ejections)
1.1.2.5.7.1.1 Determine Magnitude of Solar Radiation Impinging on Atmosphere ^ *
1.1.2.5.7.1.2 Determine Time of Onset ^ # *
1.1.2.5.7.1.3 Calculate Duration ^ # *
1.1.2.5.7.2 Determine Regions (Space, Polar, Mid-Latitude) Where High Energy (> 100 MeV) of Solar Radiation Exists ^ # *
1.1.2.5.7.3 Observe Geomagnetic Storm Activity +
1.1.2.5.7.3.1 Determine Location of Geomagnetic Storm Activity ^ # *
1.1.2.5.7.3.2 Determine Onset of Geomagnetic Storm Activity ^ # *
1.1.2.5.7.3.3 Determine Duration of Geomagnetic Storm Activity ^ # *

The following list includes the functions and subfunctions for Forecast Weather F 1.1.5 as shown in Figure B-3. Because the majority of forecasts will be probabilistic, the following identifies those that are very likely to be probabilistic with a WP (With Probability). In addition, in the interest of brevity, we eliminated in this list the “F 1.” that precedes all of the Forecast Weather function and subfunction numbers. For example, the hierarchy for “F 1.1.5 Forecast Weather” (in Figure B-3) becomes “1.5 Forecast Weather”:

1.5 Forecast Weather (With Probability (WP)) ^ # *
1.5.1 Forecast Surface Weather (WP) ^ # * ~ %
1.5.1.1 Forecast Terminal IFR Conditions (WP) ^ # * ~
1.5.1.2 Forecast Frost (WP) ^ %
1.5.1.3 Forecast Surface Winds (WP) ^ # *
1.5.1.3.1 Forecast Wind Direction (WP) ^ # * ~
1.5.1.3.2 Forecast Wind Speed (WP) ^ # * ~
1.5.1.3.3 Forecast Occurrence of Variable Winds (WP) ^ # *
1.5.1.3.4 Forecast Occurrence of Wind Shifts (WP) ^ # * ~

1.5.1.3.4.1	Forecast Duration of Wind Shifts	^ # *
1.5.1.3.5	Forecast Peak Winds	^ #
1.5.1.3.6	Forecast Location of Wind Gusts (WP)	^ # *
1.5.1.3.6.1	Forecast Wind Gust Speed (WP)	^ # *
1.5.1.3.6.2	Forecast Wind Gust Direction (WP)	^ # * ~
1.5.1.3.7	Forecast Calm Winds (WP)	^ #
1.5.1.3.8	Forecast Runway Winds (WP)	^ # *
1.5.1.3.8.1	Forecast Winds at Runway Threshold	^ #
1.5.1.3.8.2	Forecast Winds at Runway Departure	^ #
1.5.1.4	**Forecast Airport Surface Temperature (WP)**	^ #
1.5.1.4.1	Forecast Surface Dewpoint Temperature	^ #
1.5.1.4.2	Forecast Maximum Surface Temperature (WP)	^ %
1.5.1.4.3	Forecast Ground Temperature	^
1.5.1.4.4	Forecast Relative Humidity	^
1.5.1.5	**Forecast Airport Surface Obscurations (WP)**	^ # * %
1.5.1.5.1	Forecast Areas of Widespread Low Visibility (WP)	^ # *
1.5.1.5.1.1	Forecast Fog (WP) at Airport at Designated Airports	^ # * ~ %
1.5.1.5.1.2	Forecast Haze (WP) at Designated Airports	^ # * ~ %
1.5.1.5.1.3	Forecast Smoke at Designated Airports	^ # * ~ %
1.5.1.5.1.4	Forecast Volcanic Ash Impacting Airport Operations	^ # * ~ %
1.5.1.5.2	Forecast Obscurations less than 6,000' for Areas Beyond Airports	^ # *
1.5.1.5.3	Forecast Vertical Extent of Surface Obscuration (WP) at Designated Airports	^ #
1.5.1.5.4	Forecast Horizontal Extent of Surface Obscuration (WP) at Designated Airports	^ # * ~ %
1.5.1.5.5	Forecast Low Clouds (WP) at Designated Airports	^ # * ~
1.5.1.5.6	Forecast Ceilings (WP) at Designated Airports	^ # * ~
1.5.1.5.7	Forecast Low Drifting Snow at the Airport	^ # %
1.5.1.5.8	Forecast Blowing Snow at Airport	^ # %
1.5.1.5.9	Forecast Blowing Spray at Airport	^ #
1.5.1.6	**Forecast Precipitation +**	
1.5.1.6.1	Forecast Liquid Precipitation +	
1.5.1.6.1.1	Forecast Horizontal Extent of Liquid Precipitation	^ # * ~
1.5.1.6.1.2	Forecast Amount (inches) of Liquid Precipitation (WP)	^ # * ~
1.5.1.6.1.3	Forecast Rain Intensity (WP) (inches/hour)	^ # * ~ %
1.5.1.6.1.4	Forecast Occurrence of Moderate or Greater Rain Showers (WP)	^ # * ~
1.5.1.6.1.5	Forecast Liquid Precipitation Movement	^ # * ~
1.5.1.6.1.5.1	Forecast Direction of Precipitation Movement	^ # * ~
1.5.1.6.1.5.2	Forecast Speed of Precipitation Movement	^ # * ~
1.5.1.6.1.6	Forecast Beginning Time of Liquid Precipitation	^ # * ~
1.5.1.6.1.7	Forecast Ending Time of Liquid Precipitation	^ # * ~

1.5.1.6.2	Forecast Freezing Precipitation Type (WP)	^ # * ~ %
1.5.1.6.2.1	Forecast Freezing Rain (WP)	^ # * ~ %
1.5.1.6.2.2	Forecast Freezing Drizzle (WP)	^ # * ~ %
1.5.1.6.2.3	Forecast Ice Accretion Rate (WP)	^ # ~ %
1.5.1.6.2.4	Forecast Surface Icing Accumulation (WP)	^ # ~ %
1.5.1.6.2.5	Forecast Beginning Time of Freezing Precipitation (WP)	^ # * ~ %
1.5.1.6.2.6	Forecast Ending Time of Freezing Precipitation	^ # * ~ %
1.5.1.6.3	Forecast Solid Precipitation (WP)	^ # * ~ %
1.5.1.6.3.1	Forecast Snow (WP)	^ # * ~ %
1.5.1.6.3.1.1	Forecast Snow Intensity (WP) (inches/hour)	^ # * ~ %
1.5.1.6.3.1.2	Forecast Snowfall Accumulation	^ # * %
1.5.1.6.3.1.3	Forecast Snow Shower (WP)	^ # * ~ %
1.5.1.6.3.1.4	Forecast Liquid Water Equivalent of Snowfall Accumulation (WP)	^ # * ~ %
1.5.1.6.3.1.5	Forecast Beginning Time of Snowfall	^ # * ~ %
1.5.1.6.3.1.6	Forecast Ending Time of Snowfall	^ # * ~ %
1.5.1.6.3.2	Forecast Hail (WP)	^ # * ~
1.5.1.6.3.2.1	Forecast Hail size (WP) ½ inch or greater	^ # * ~ %
1.5.1.6.3.2.2	Forecast Horizontal Extent of Hail	^ # * ~
1.5.1.6.3.3	Forecast Ice Pellets (WP)	^ # * ~
1.5.1.6.3.3.1	Forecast Horizontal Extent of Ice Pellets	^ # * ~
1.5.1.6.3.3.2	Forecast Ice Pellet Intensity (WP)	^ # * ~
1.5.1.6.3.4	Forecast Snow Pellets (WP)	^ # ~
1.5.1.6.3.5	Forecast Ice Crystals (WP)	^ # * ~
1.5.1.6.3.6	Forecast Liquid Water Equivalent of Solid Precipitation Over Time Increments (inches/hour) (WP)	^ # * ~ %
1.5.1.7	**Forecast Surface Visibility (WP)**	
1.5.1.7.1	Forecast Airport Visibility (WP)	^ # * ~
1.5.1.7.2	Forecast RVR (Average) (WP)	^ # * ~
1.5.1.8	**Forecast Sky Conditions (WP)**	^ # ~
1.5.1.8.1	Forecast Sky Cover (WP)	^ # ~
1.5.1.8.2	Forecast Dominant Cloud Layer Base Heights	^ # ~
1.5.1.8.3	Forecast Ceiling (WP)	^ # * ~
1.5.1.8.3.1	Forecast Horizontal Extent of Cloud Ceiling	^ #
1.5.1.8.4	Forecast Cloud Types Expected During next 24 hours	^ # ~
1.5.1.8.5	Forecast Cloud Stratification (Types Versus Layers)	^ # ~
1.5.1.9	**Forecast Ocean Surface Conditions by FIR[11] (for Dispatch and Oceanic)**	^ #
1.5.1.9.1	Forecast Ocean Wave and Swell Heights (WP)	^ #

[11] FIR = Flight Information Region.

1.5.1.9.2 Forecast Ocean Wave and Swell Direction (WP) ^ #

1.5.1.10 Forecast Large Lake Surface Conditions

1.5.1.10.1 Forecast Large Lake Wave and Swell Heights (WP) ^ #

1.5.1.10.2 Forecast Large Lake Wave and Swell Direction (WP) ^ #

1.5.1.11 Forecast Other Weather

1.5.1.11.1 Forecast Wind Direction From Surface to 100 kft at Other Than Airports ^ #

1.5.1.11.2 Forecast Wind Speed From Surface to 100 kft at Other Than Airports ^ #

1.5.1.11.3 Forecast Position of the Jet Stream for FAA-controlled FIRs for 6, 12, 18, 24, and 36 hours ^ # *

1.5.1.11.4 Forecast Temperature from Surface to 60 kft at Other Than Airports ^ #

1.5.1.11.5 Forecast Thunderstorms ^ # * ~

1.5.1.11.5.1 Forecast Direction of Thunderstorm Movement (WP) ^ # * ~ %

1.5.1.11.5.2 Forecast Speed of Thunderstorm Movement (WP) ^ # * ~ %

1.5.1.11.5.3 Forecast Location of Thunderstorm Cell ^ # * ~ %

1.5.1.11.5.4 Forecast Intensity of Thunderstorm Cell ^ # * ~ %

1.5.1.11.5.5 Forecast Horizontal Extent of Precipitation Associated With TS (WP) ^ # * ~

1.5.1.11.5.6 Forecast Precipitation Accumulation Associated with TS (WP) ^ # * ~

1.5.1.11.5.7 Forecast Locations of Convective Initiation (WP) ^ # *

1.5.1.11.5.8 Forecast Locations of Thunderstorm Growth (WP) ^ # * ~

1.5.1.11.5.9 Forecast Locations of Thunderstorm Decay (WP) ^ # * ~

1.5.1.11.6 Forecast Total Lightning ^ # * ~ %

1.5.1.11.6.1 Forecast Horizontal Extent of Intra-Cloud Lightning (WP) ^ # * ~ %

1.5.1.11.6.2 Forecast Vertical Extent (FL) of Intra-Cloud Lightning (WP) ^ # * ~

1.5.1.11.6.3 Forecast Horizontal Extent of Inter-Cloud Lightning (WP) ^ # * ~ %

1.5.1.11.6.4 Forecast Vertical Extent (FL) of Inter-Cloud Lightning ^ # * ~

1.5.1.11.6.5 Forecast Location(s) of Groundstroke Lightning (WP) ^ # * ~ %

1.5.1.11.6.6 Forecast When Lightning Is Imminent[12] ^ # * ~ %

1.5.1.11.7 Forecast Location of Mesocyclones (WP) ^ # * ~

1.5.1.11.7.1 Forecast Mesocyclone Movement Speed (WP) ^ # * ~

1.5.1.11.7.2 Forecast Mesocyclone Movement Direction (WP) ^ # * ~

1.5.1.11.8 Forecast occurrence of Low-Level Wind Shear/Microburst activity “at” or “in Vicinity” of Designated Airports/Spaceports (WP) ^ # * ~

1.5.1.11.9 Forecast Liquid Stratiform Precipitation ^ # * ~

1.5.1.11.10 Forecast Horizontal Extent of Liquid Stratiform Precipitation (WP) ^ # * ~

1.5.1.11.11 Forecast Onset of Liquid Stratiform Precipitation (WP) ^ # * ~

1.5.1.11.12 Forecast Duration of Liquid Stratiform Precipitation (WP) ^ # * ~

[12] Imminent = Lightning expected within 5 to 10 minutes.

1.5.1.12	**Forecast Solid Stratiform Precipitation**	^ # * ~ %
1.5.1.12.1	Forecast Horizontal Extent of Solid Stratiform Precipitation (WP)	^ # * ~ %
1.5.1.12.2	Forecast Onset of Solid Stratiform Precipitation (WP)	^ # * ~ %
1.5.1.12.3	Forecast Duration of Solid Stratiform Precipitation (WP)	^ # * ~ %
1.5.1.13	**Forecast Wake Vortex (WV) at Designated Airports**	^ # * ~
1.5.1.13.1	Forecast WV Displacement at Designated Airports (WP)	^ # *
1.5.1.13.2	Forecast WV Dissipation at Designated Airports (WP)	^ # *
1.5.1.14	**Observe Hurricanes/Typhoons +**	^ # *
1.5.1.14.1	Forecast Hurricane/Typhoon Category	^ # *
1.5.1.14.2	Forecast Hurricane/Typhoon Category Changes	^ # *
1.5.1.14.3	Forecast Hurricane/Typhoon Movement Speed	^ # *
1.5.1.14.4	Forecast Hurricane/Typhoon Movement Direction	^ # *
1.5.2	**Forecast Weather Aloft**	^ # *
1.5.2.1	**Forecast Winds Aloft from 6 Kft to 100 Kft**	^ # ~
1.5.2.1.1	Forecast Wind Direction Surface to 100 Kft	^ #
1.5.2.1.2	Forecast Wind Speed Surface to 100 Kft	^ #
1.5.2.1.3	Forecast Wind Compression profile to 25 Kft for Designated Airports	^ # * ~
1.5.2.1.4	Forecast Vertical Wind Profile up to 100 Kft for Spaceports	^ #
1.5.2.2	**Forecast Regions of In-flight Icing (WP)**	^ # * ~
1.5.2.2.1	Forecast Horizontal Extent of In-flight Icing (WP)	^ # * ~
1.5.2.2.2	Forecast Vertical Extent of In-flight Icing (WP)	^ # * ~
1.5.2.2.3	Forecast Intensity of In-flight Icing Accumulation by Aircraft Type (WP)	^ # * ~
1.5.2.2.4	Forecast Region(s) of Supercooled Liquid Droplets (WP)	^ # * ~
1.5.2.2.5	Forecast Type of In-flight Icing Expected (e.g., Rime, SLD) (WP)	^ # *
1.5.2.3	**Forecast Sky Conditions Aloft (WP)**	
1.5.2.3.1	Forecast Flight Level of Cloud Tops (Above Echo Tops) (WP)	^ # *
1.5.2.3.2	Forecast Altitude of Cloud Layer Height Bases (WP)	^ # * ~
1.5.2.3.3	Forecast Cloud Layer Thickness (WP)	^ # *
1.5.2.4	**Forecast Obscurations (WP) Aloft**	*
1.5.2.4.1	Forecast Slant Range Visibility at Designated Airports (WP) for Approach and Departure Corridors	^ # *
1.5.2.4.2	Forecast Horizontal Extent of Smoke (WP)	^ #
1.5.2.4.3	Forecast Vertical Extent (FL) of Smoke (WP)	^ #
1.5.2.4.4	Forecast Horizontal Extent of Blowing Dust (WP)	^ #
1.5.2.4.5	Forecast Vertical Extent (FL) of Blowing Dust (WP)	^ #
1.5.2.5	**Forecast Precipitation Aloft**	^ #
1.5.2.5.1	Forecast Horizontal Extent of Liquid Precipitation (WP)	^ #
1.5.2.5.1.1	Forecast Vertical Extent (FL) of Liquid Precipitation (WP)	^ #
1.5.2.5.1.2	Forecast Rain Intensity (WP) (moderate or greater)	^ # *
1.5.2.5.1.3	Forecast Horizontal Extent of Drizzle (WP)	^ #

1.5.2.5.2 Forecast Solid Precipitation Aloft ^ # *
1.5.2.5.2.1 Forecast Horizontal Extent of Hail (WP) ^ # *
1.5.2.5.2.2 Forecast Vertical Extent (FL) of Hail (WP) ^ # *
1.5.2.5.2.3 Forecast Snow Intensity (Moderate or Greater) (WP) ^ #
1.5.2.5.2.4 Forecast Ice Pellets Intensity (Moderate or Greater) (WP) ^ # *
1.5.2.5.3 Forecast Location of Freezing Precipitation (WP) ^ # * ~
1.5.2.5.3.1 Forecast Freezing Level Aloft (WP) ^ # * ~
1.5.2.5.3.2 Forecast Horizontal Extent of Freezing Precipitation (WP) ^ # * ~

1.5.2.6 Forecast Turbulence (WP)

1.5.2.6.1 Forecast 3-D Extent of Convective Induced Turbulence (CIT) Within 30nm of TS (WP) ^ # * ~
1.5.2.6.2 Forecast Intensity of CIT (WP) ^ # * ~
1.5.2.6.3 Forecast 3-D Location(s) of Clear Air Turbulence (CAT) (WP) ^ # * ~
1.5.2.6.4 Forecast 3-D Locations(s) of CAT Due to Topography (e.g., Mountain Waves, Rotors) (WP) ^ # * ~
1.5.2.6.5 Forecast Intensity of CAT (WP) ^ # * ~

1.5.2.7 Forecast Space Weather (e.g., Solar Flares, Coronal Mass Ejections)

1.5.2.7.1 Forecast Solar Radiation Activity Affecting Aviation for 12, 24, 36, and 48 hours in Advance ^ # *
1.5.2.7.2 Forecast Regions (e.g., Space, Polar, High-Latitude, and Mid-Latitude) Susceptible to Moderate Energy Levels (> 10MeV) of Solar Radiation for 12, 24, 36 and 48 Hours in Advance ^ # *
1.5.2.7.3 Forecast Regions (e.g., Space, Polar, High-Latitude, and Mid-Latitude) Susceptible to High Energy Levels (> 100 MeV) of Solar Radiation for 12, 24, 36 and 48 Hours in Advance ^ # *
1.5.2.7.4 Forecast Where Solar Activity Significantly Degrades HF Comms (WP) 12, 24, and 36 Hours in Advance ^ # *
1.5.2.7.5 Forecast Where Solar Activity Will Significantly Degrade Navigation Systems (WP) 12, 24, and 36 Hours in Advance ^ # * ~
1.5.2.7.6 Forecast Intensity of Solar Radiation (WP) 12, 24, and 36 Hours in Advance ^ # * ~
1.5.2.7.7 Forecast Period of Solar Radiation Maximum Exposure (WP) 12, 24, and 36 hours in Advance ^ # ~
1.5.2.7.8 Forecast Duration of Solar Radiation (WP) 12, 24, and 36 hours in Advance ^ # ~

1.5.2.8 Forecast Other Weather (Aloft) ^ # *

1.5.2.8.1 Forecast Volcanic Ash Dispersion (WP) ^ # * ~
1.5.2.8.2 Forecast Movement of Volcanic Ash Cloud (WP) ^ # * ~
1.5.2.8.3 Forecast 3-D Extent of Volcanic Ash Cloud (WP) ^ # * ~

User functions that require weather support but that are not performed as a weather function, per se, are listed below. In the NextGen era, a decision support tool (DST) would perform this

function (for the User) to assess the operational impact after ingesting the weather data/information.

1.3.1 Determine Runway Braking Conditions Due to Rain ^ # * ~ %

1.3.2 Determine Runway Braking Conditions Due to Snow ^ # * ~ %

1.3.3 Determine Runway Braking Conditions to Surface Icing ^ # * %

1.3.4 Observe Volcanic Eruptions (Svc Standard Level A) ^

1.3.5 Forecast the Impact of Thunderstorms on ARTCC Sector Capacity (WP) # *

1.3.6 Forecast the Impact of Thunderstorm on Route Capacity (WP) ^ # *

1.3.7 Forecast Proximity of Heavy Precipitation (> 1.5"/hour) to Airport/Spaceport (WP) ^ # * ~

1.3.8 Determine When Hurricane/Typhoon-Strength Winds Will Impact FAA-Controlled airspace ^ # * ~

1.3.9 Determine When Hurricane/Typhoon-Related Precipitation Will Impact FAA-Controlled Airspace ^ # * ~

1.3.10 Calculate Snowfall Intensity ^ # * %

1.3.11 Determine Surface Icing Accretion Accumulation for 1, 3, and 6 hours ^ # *

1.3.12 Forecast Weather Traffic Impacts (e.g., thunderstorm, obscurations) to Arrival/Departure Corridors at Designated Airports Out 2 to 4 hours ^ # * ~

1.3.13 Determine Snow Falling Rapidly at Designated Airports ^ # %

1.3.14 Forecast Impacts at Arrival/Departure "Corner Posts" Out to 50nm at Designated Airports 4-6 Hours in Advance # *

APPENDIX C. FUNCTIONAL TRACEABILITY OF NEXTGEN USERS

The following provides a snapshot or overview of the Observe and Forecast weather functions in Appendix B and the operational decision-making functions they support. More detail is available in Appendix B.

NextGen ConOps Ver 2.0 Operational Functions Supported / Observe & Forecast Functions & Subfunctions	Support Operators 1	Support Air Traffic Ops	Support Traffic Mgmt	Support Terminal Airspace Configuration	Support Ground Ops
Observe Surface Present Weather					
Precipitation	X	X	X	X	X
Liquid Precipitation	X	X	X		
Solid Precipitation	X	X	X		X
Freezing Precipitation	X	X	X	X	X
Obscurations (to Visibility)	X	X	X	X	X
Thunderstorms and attributes (i.e., Hail, Lightning, Wind shear, Turbulence, Icing, Tornadoes, Gusting Winds)	X	X	X	X	X
Wind Shear/Microburst	X	X	X		X
Tornadic Activity (Funnel Cloud, Tornado, Water Spout)	X	X	X	X	X
Wake Vortex at Designated Airports	X	X	X	X	
Winds (i.e., Wind Speed/Dir, Gust, Wind Shift, Peak Wind, Runway Winds, Variable)	X	X	X	X	
Wind Speed/Direction from Surface to 100 Kft	X	X	X	X	
Surface Visibility	X	X	X	X	
RVR	X	X	X	X	
Station Pressure (Determine Altimeter Setting)	X	X			
Sky Cover/Conditions	X	X	X	X	
Airport Temperature/Dew Point Temperature	X	X			X
Ocean/Large Lake Surface Conditions (Wave/Swell Height and Direction)	X	X			
Observe Weather Aloft					
Winds	X	X	X (Oceanic)	X	
Obscurations	X	X	X	X	
Temperature	X		X (Oceanic)		
Precipitation					
Liquid	X	X			
Solid	X	X	X		
Freezing Level/Supercooled Liquid Drops	X	X	X		
Vertical Extent of In-Flight Icing	X	X	X		
Volcanic Ash Cloud (3D Extent)	X	X	X		
TS Cloud Tops	X	X	X		
Turbulence	X	X	X	X (<18Kft)	
Cloud Lighting	X	X	X	X	
Space Weather (Solar Radiation; Effects on Humans, Navigation, Comms, in Space, Polar, and Mid-Latitude Regions)	X	X	X		
Forecast Surface Weather (Probabilistic)					
Winds (i.e., Wind Speed/Dir, Gust, Wind Shift, Variable Winds, Runway Winds)	X	X	X	X	
Airport Temperature/Relative Humidity	X	X			X
Maximum Temperature	X	X			X
Obscurations					

NextGen ConOps Ver 2.0 Operational Functions Supported / Observe & Forecast Functions & Subfunctions	Support Operators 1	Support Air Traffic Ops	Support Traffic Mgmt	Support Terminal Airspace Configuration	Support Ground Ops
At All Airports	X	X		X	X
Widespread Areas of Low Visibility (Away From Airports)	X	X			
Vertical Extent at Super Density Airports	X	X	X	X	
Horizontal Extent at Super Density Airports	X	X	X	X	X
Precipitation					
Liquid (Rain, Drizzle)	X	X	X	X	X
Solid (Snow, Hail, Ice/Snow Pellets)	X	X	X	X	X
Freezing (Rain, Drizzle)	X	X	X	X	X
Visibility	X	X	X	X	
Sky Cover/Conditions	X	X	X	X	
Ocean/Large Lake Surface Conditions	X	X			
Wind Shear/Microburst	X	X	X		
Wake Vortex at Designated Airports					
Horizontal Displacement	X	X	X		
Dissipation	X	X	X		
Forecast Weather Aloft					
Winds	X	X	X	X	
In-Flight Icing	X	X	X	X	
Horizontal Extent	X	X	X	X	
Layer(s) Vertical Extent	X	X	X	X	
Sky Cover/Conditions	X	X	X	X	
Obscurations					
Slant Range Visibility at Designated Airports	X	X	X		
Smoke/Dust/Mist/Fog	X	X	X		
Precipitation					
Liquid	X	X	X	X	
Solid	X	X	X	X	X
Freezing Level	X	X	X	X < 18Kft	
Turbulence					
Convective Induced Turbulence (CIT)	X	X	X	X < 18Kft	
Clear Air Turbulence (CAT)	X	X	X	X < 18Kft	
Topography Induced Turbulence (e.g., Mountain Waves, Rotors)	X	X	X	X < 18Kft	
Space Weather	X	X	X	X	
Volcanic Ash 3-D Dispersion	X	X	X	X	
Thunderstorm for Location, Movement Speed/Direction (2, 4, 8, 12, and 24 Hours)	X	X	X	X	X
Impact of TS on ARTCC Sector Capacity	X	X	X		
Impact of TS on Route Capacity	X	X	X		

APPENDIX D. TRACEABILITY TABLE

The Joint Planning and Development Office (JPDO) Weather Functional Requirements Study Team extracted an initial set of Four-Dimensional Weather Single Authoritative Source (4-D Wx SAS) functions from the ConOps for the Next Generation Air Transportation System v2.0 (NextGen ConOps v2.0) and the Weather Concept of Operations v1.0 (Weather ConOps v1.0). The Traceability Subteam was responsible for tracing these 4-D Wx SAS functions to the ConOps documents. The Traceability Subteam modified the initial set of functions for elements such as consistency and clarity and to remove functions that were not 4-D Wx SAS functions. For completeness, the Traceability Subteam also extracted and derived additional functions from the ConOps documents. In this context, “extracted” indicates that a function was directly addressed in either or both ConOps documents; “derived” indicates that a function was indirectly addressed. Functions could also be derived from other documents (e.g., policies, regulations, orders, Federal Aviation Administration [FAA] National Airspace System [NAS] Enterprise Architecture) or from subject matter experts (SME).

The Traceability Subteam developed a traceability table to record the function ID, function text, applicable ConOps paragraph number, applicable stakeholders, and source traceability code, as follows:

1. Extracted from NextGen ConOps v2.0
2. Extracted from Weather ConOps v1.0
3. Derived from either or both ConOps documents
4. Derived from other documents (e.g., policies, regulations, orders, FAA NAS Enterprise Architecture)
5. Derived from SMEs.

Note: The Traceability Subteam also developed a traceability table for the 4-D Wx SAS that includes the referenced ConOps paragraph text (in addition to the above information). Based on its length, the table was excluded from this report. However, it is available electronically upon request.

Function ID	Function	Ref. Paragraph NextGen ConOps, V2.0	Ref. Paragraph Wx ConOps, V1.0	Traceability Code	Stakeholder
F1.1.9	Manage 4-D Weather SAS.	5.3.1	Executive Summary	1, 2	All Stakeholders
F1.1.9.1	Acquire weather information from authorized weather sources.	5.3.1, 5.3.3	5.5, 5.5.1	1, 2	All Stakeholders
F1.1.9.1.1	Acquire weather information from authorized ground-based weather sources.				
F1.1.9.1.1.1	Collect weather information from airfield sensors.				
F1.1.9.1.1.2	Receive weather information from airfield sensors.				
F1.1.9.1.2	Acquire weather information from authorized ocean surface-based weather sources.				
F1.1.9.1.2.1	Collect weather information from ships.				
F1.1.9.1.2.2	Collect weather information from buoys.				
F1.1.9.1.2.3	Receive weather information from ships.				
F1.1.9.1.2.4	Receive weather information from buoys.				
F1.1.9.1.3	Acquire weather information from authorized airborne-based weather sources.				
F1.1.9.1.3.1	Collect weather information from aircraft.				
F1.1.9.1.3.1.1	Collect weather information from manned aircraft sensors.				
F1.1.9.1.3.1.2	Collect weather information from unmanned aircraft sensors.				
F1.1.9.1.3.1.3	Collect weather information from rawinsondes.				
F1.1.9.1.3.1.4	Collect weather information from pibals.				
F1.1.9.1.3.2	Receive weather information from aircraft.				
F1.1.9.1.3.2.1	Receive weather information from manned aircraft sensors.				
F1.1.9.1.3.2.2	Receive weather information from unmanned aircraft sensors.				
F1.1.9.1.3.2.3	Receive weather information from rawinsondes.				
F1.1.9.1.3.2.4	Receive weather information from pibals.				
F1.1.9.1.4	Acquire weather information from authorized space-based weather sources.				
F1.1.9.1.4.1	Collect weather information from atmospheric-sensing satellites.				
F1.1.9.1.4.2	Receive weather information from atmospheric-sensing satellites.				
F1.1.9.1.5	Acquire weather information from authorized observers.				
F1.1.9.1.5.1	Receive weather information from certified observers.				
F1.1.9.1.5.2	Receive weather information from air traffic controllers.				
F1.1.9.1.5.3	Receive weather information from aircraft operators.				
F1.1.9.2	Integrate weather information from authorized weather sources.	5.3.1, 5.3.3	Executive Summary, 2.4.2, 4.6	1, 2	All Stakeholders
F1.1.9.2.1	Integrate weather observations from authorized ground-, airborne-, ocean surface-, space-based, and human weather sources.				
F1.1.9.2.2	Integrate weather forecasts from authorized ground-, airborne-, ocean surface-, space-based, and human weather sources.				

Function ID	Function	Ref. Paragraph NextGen ConOps, V2.0	Ref. Paragraph Wx ConOps, V1.0	Traceability Code	Stakeholder
F1.1.9.3	Analyze integrated weather information.	4.3.2, 5.3.3	4.6	1, 2	All Stakeholders
F1.1.9.3.1	Analyze integrated weather observations.				
F1.1.9.3.2	Analyze integrated forecasts.				
F1.1.9.4	Quantify weather information.	1.2.2.6, 5.3.1, 5.3.3	Executive Summary, 5.1.1, 5.3.3	1, 2	All Stakeholders
F1.1.9.4.1	Quantify observed weather information.				
F1.1.9.4.1.1	Quantify date and time of observed weather.				
F1.1.9.4.1.2	Quantify location of observed weather.				
F1.1.9.4.1.2.1	Quantify latitude of observed weather.				
F1.1.9.4.1.2.2	Quantify longitude of observed weather.				
F1.1.9.4.1.2.3	Quantify altitude of observed weather.				
F1.1.9.4.1.3	Quantify intensity of observed weather.				
F1.1.9.4.2	Quantify forecast weather information.				
F1.1.9.4.2.1	Quantify date and time of forecast weather.				
F1.1.9.4.2.2	Quantify location of forecast weather.				
F1.1.9.4.2.2.1	Quantify latitude of forecast weather.				
F1.1.9.4.2.2.2	Quantify longitude of forecast weather.				
F1.1.9.4.2.2.3	Quantify altitude of forecast weather.				
F1.1.9.4.2.3	Quantify intensity of forecast weather.				
F1.1.9.4.2.4	Quantify probability of forecast weather.				
F1.1.9.5	Perform quality control on weather information.	1.2.2.2, 5.3.3	2.1.1, 4, 5.3.3	3	All Stakeholders
F1.1.9.6	Format weather information.	2.7.1, 4.1, 5.3.2, 5.3.3, 5.8, 5.9	Executive Summary, 2.2, 2.4.1, 2.6.1, 3.3, 4.3, 4.4, 5.1.1, 5.3.3, 5.5	1, 2	All Stakeholders
F1.1.9.6.1	Format weather information in required digital format.				
F1.1.9.6.2	Format weather information in required resolution scale.				
F1.1.9.6.2.1	Format weather information in required spatial resolution scale.				
F1.1.9.6.2.1.1	Format weather information in required terminal resolution scale.				
F1.1.9.6.2.1.2	Format weather information in required en route resolution scale.				
F1.1.9.6.2.1.3	Format weather information in required oceanic resolution scale.				
F1.1.9.6.2.2	Format weather information in required temporal resolution scale.				
F1.1.9.6.3	Format weather information in required units of measurement.				
F1.1.9.7	Generate 4-D Weather SAS information.	Executive Summary, 1.2.2.6, Table 5-1, 5.3.1, 5.3.2, 5.3.3	2.2, 2.4, 4.6, 5.4.1	1, 2	All Stakeholders
F1.1.9.7.1	Generate 4-D Weather SAS observations.				
F1.1.9.7.2	Generate 4-D Weather SAS analyses.				
F1.1.9.7.3	Generate 4-D Weather SAS forecasts.				

Function ID	Function	Ref. Paragraph NextGen ConOps, V2.0	Ref. Paragraph Wx ConOps, V1.0	Traceability Code	Stakeholder
F1.1.9.8	Store 4-D Weather SAS information.	2.1.2	4.6	2, 3	All Stakeholders
F1.1.9.8.1	Store 4-D Weather SAS observations.				
F1.1.9.8.2	Store 4-D Weather SAS analyses.				
F1.1.9.8.3	Store 4-D Weather SAS forecasts.				
F1.1.9.9	Secure 4-D Weather SAS information.	1.2, 1.2.2.2, 2.1.1, 2.1.2, 4.1.1, 4.4, 5.3.3, 6.1.1	2.2, 4.8	1, 2	All Stakeholders
F1.1.9.9.1	Provide 4-D Weather SAS information access to authorized users.				
F1.1.9.9.2	Provide 4-D Weather SAS information access to authorized systems.				
F1.1.9.10	Receive requests for 4-D Weather SAS information.	1.2.2.2, 2.7.1, 5.1, 5.3.1, 5.3.2	Executive Summary, 2.2.5, 4.3, 5.1.1	1, 2	All Stakeholders
F1.1.9.10.1	Receive requests for 4-D Weather SAS information from authorized users.				
F1.1.9.10.2	Receive requests for 4-D Weather SAS information from authorized systems.				
F1.1.9.11	Process requests for 4-D Weather SAS information.	4.4	2.2, 5.1.1, 5.1.2	3	All Stakeholders
F1.1.9.11.1	Process requests for 4-D Weather SAS information from authorized users.				
F1.1.9.11.2	Process requests for 4-D Weather SAS information from authorized systems.				
F1.1.9.12	Provide 4-D Weather SAS information.	See lower-level functions.	See lower-level functions.	See lower-level functions.	See lower-level functions.
F1.1.9.12.1	Provide 4-D Weather SAS information to authorized users.	Executive Summary, 4.1.1, Table 5-1, 5.3.2	2.2, 2.4.2, 3.2	1, 2	Airport Operators Airport Tenants ANSPs Flight Operators Security and Defense Providers Weather Service Providers
F1.1.9.12.2	Provide 4-D Weather SAS information to authorized systems.	Executive Summary, 1.2.2.6, 4.1.1, 5.3.1, 5.3.2	2.2.3, 2.4.1, 2.7.2, 3.4	1, 2	Airport Operators ANSPs Flight Operators Security and Defense Providers

Function ID	Function	Ref. Paragraph NextGen ConOps, V2.0	Ref. Paragraph Wx ConOps, V1.0	Traceability Code	Stakeholder
F1.1.9.12.3	Provide 4-D Weather SAS information to support NextGen operational decisionmaking.	Executive Summary, 1.2, 1.2.2.6, 2.1.1, 4.1.1, 5.3.1, 5.3.2	Executive Summary, 2.4, 2.4.2, 2.7.2, 3.2, 4.1.b, 4.1.c	1, 2	Airport Operators Airport Tenants ANSPs Flight Operators Security and Defense Providers Weather Service Providers
F1.1.9.12.3.1	Provide 4-D Weather SAS information to support air traffic management operations.	1.2, 1.2.2.6, 2.1.1.1, Table 2-1, Table 2-2, 2.3.2.2, 2.4, 2.4.1	Executive Summary, 2.2.1, 2.7.5, 4.1.b	1, 2	Airport Operators Airport Tenants ANSPs Customers Flight Operators Regulatory Authorities Security and Defense Providers
F1.1.9.12.3.1.1	Provide 4-D Weather SAS information to support capacity management operations.	2.3.2.1, 3.3.1.2.3, 5.3.1, 5.3.2, 5.3.3, 5.7	Executive Summary, 2.7.2, 5.2, 5.2.1, 5.2.2	1, 2	ANSPs Flight Operators
F1.1.9.12.3.1.1.1	Provide 4-D Weather SAS information to support short-term capacity management.				
F1.1.9.12.3.1.1.1.1	Provide 4-D Weather SAS information to support terminal airspace configuration.				
F1.1.9.12.3.1.1.1.1.1	Provide 4-D Weather SAS terminal weather observations to support dynamic terminal airspace configuration.				
F1.1.9.12.3.1.1.1.1.2	Provide 4-D Weather SAS short-term terminal weather forecasts to support dynamic terminal airspace configuration.				
F1.1.9.12.3.1.1.2	Provide 4-D Weather SAS information to support long-term capacity management.				
F1.1.9.12.3.1.2	Provide 4-D Weather SAS information to support flow contingency management operations.	2.3.2.2, 2.4.5	4.10, 5.1.2, 5.3.1, 5.3.3	1, 2	ANSPs Flight Operators
F1.1.9.12.3.1.3	Provide 4-D Weather SAS information to support trajectory management operations.	2.1.1.1, 2.4, 2.4.1, 2.4.2, 2.4.6, 2.4.7, 5.3.1, 5.3.2	Executive Summary, 2.7.2, 5.3.1, 5.4.1	1, 2	ANSPs Flight Operators
F1.1.9.12.3.1.4	Provide 4-D Weather SAS information to support separation management operations.	2.4.5, 2.4.6	5.1.2, 5.2.3, 5.4.1, 5.5	1, 2	ANSPs Flight Operators

Function ID	Function	Ref. Paragraph NextGen ConOps, V2.0	Ref. Paragraph Wx ConOps, V1.0	Traceability Code	Stakeholder
F1.1.9.12.3.2	Provide 4-D Weather SAS information to support flight operator operations.	1.2.1, 1.2.2.6, 2.7.1	Executive Summary, 2.2.3, 2.8, 3.2, 3.4, 4.1.c, 5.1.1	1, 2	ANSPs Flight Operators
F1.1.9.12.3.2.1	Provide 4-D Weather SAS information to support aircraft transitioning from NAS airspace to oceanic/international airspace.	2.1.1.1, 2.3.2, 2.4.7, 4.3.2, Table 5-2	5.5		
F1.1.9.12.3.2.2	Provide 4-D Weather SAS information to support flight planning.	See lower-level functions.	See lower-level functions.		
F1.1.9.12.3.2.2.1	Provide 4-D Weather SAS information to support pre-flight planning.	5.3.2	Executive Summary, 2.6.1, 2.7.2, 5.1.2		
F1.1.9.12.3.2.2.1.1	Provide 4-D Weather SAS climatological information to support long-range flight planning.				
F1.1.9.12.3.2.2.2	Provide 4-D Weather SAS information to support in-flight planning.	5.3.2	5.1.2		
F1.1.9.12.3.2.3	Provide 4-D Weather SAS information to support VFR operations (involving hazardous weather situations).	2.7.1	5.4.2		
F1.1.9.12.3.2.4	Provide 4-D Weather SAS information to support unmanned aircraft system operations.	2.1.1.1, 2.7.2.2, 5.3.1	5.8, 5.8.1		
F1.1.9.12.3.3	Provide 4-D Weather SAS information to support airport operations.	Executive Summary, 1.2.2.1, 1.2.2.6, 3.3.1.2.1, 3.3.1.2.3, 3.4.1, 5.8	5.2.3	1, 2	ANSPs Airport Operators Airport Tenants Flight Operators
F1.1.9.12.3.3.1	Provide 4-D Weather SAS information to support major airport operations.				
F1.1.9.12.3.3.2	Provide 4-D Weather SAS information to support nonmajor (secondary) airport operations.	Executive Summary, 1, 1.2.2.9, 2.1.1.1, 2.3.3, 2.6, 2.8.2, 3.1, 5.3.2	Executive Summary, 2.6.1, 5.2.3	1, 2	ANSPs Airport Operators Airport Tenants Flight Operators
F1.1.9.12.3.3.2.1	Provide 4-D Weather SAS information to support non-major (secondary), towered airports.				
F1.1.9.12.3.3.2.2	Provide 4-D Weather SAS information to support non-major (secondary), non-towered airports.				
F1.1.9.12.3.3.2.3	Provide 4-D Weather SAS information to support non-major (secondary), virtual-towered airports.				
F1.1.9.12.3.3.3	Provide 4-D Weather SAS information to support airport ground operations.	3.3.1.2.1, 3.3.1.2.3, 3.4.1, 5.3.3, 5.8	5.2.3	1, 2	ANSPs Airport Operators Airport Tenants Flight Operators
F1.1.9.12.3.3.3.1	Provide 4-D Weather SAS information to support deicing operations.				
F1.1.9.12.3.3.3.2	Provide 4-D Weather SAS information to support snow removal operations.				

Function ID	Function	Ref. Paragraph NextGen ConOps, V2.0	Ref. Paragraph Wx ConOps, V1.0	Traceability Code	Stakeholder
F1.1.9.12.3.3.4	Provide 4-D Weather SAS information to support airport passenger operations.	3.4.1	3.3, 4.1, 5.1, 5.7	1, 2	ANSPs Airport Operators Airport Tenants Flight Operators
F1.1.9.12.4	Provide 4-D Weather SAS observations.	4.3.2, 5.3.1, 5.3.3	2.4, 4.6, 5.5, 5.5.1	1, 2	All Stakeholders
F1.1.9.12.5	Provide 4-D Weather SAS analyses.	4.3.2	4.6, 5.1.1	1, 2	All Stakeholders
F1.1.9.12.6	Provide 4-D Weather SAS forecasts.	2.1.1, 5.3.1, 5.3.3	Executive Summary, 2.4, 2.4.1, 2.7.2, 4.3, 5.2.2	1, 2	All Stakeholders
F1.1.9.13	Update 4-D Weather SAS information when updated weather information is received from authorized weather sources.	Executive Summary, Table 5-1, 5.3.1	2.4, 5.2.2	1, 2	ANSPs Airport Operators Customers Flight Operators Security and Defense Providers Weather Service Providers

APPENDIX E. ENTERPRISE ARCHITECTURE

NEXTGEN ENTERPRISE ARCHITECTURE—WEATHER PRODUCTS

The JPDO Enterprise Architecture Division has benefited from the combined subject matter expertise of the 4-D Cube Functional Requirements Study Group. This group has worked during the past months to define and refine the functional and performance requirements for providing weather information to the NextGen enterprise. The enterprise architect team has collaborated with the weather SMEs in their deliberations to better understand the technologies and activities required for meeting the NextGen's weather information needs. The result of this collaboration has been a proposed update to the Weather Services portion of the NextGen EA. These proposed products will be provided to the JPDO Enterprise Architecture Steering Committee (EASC) for approval to be included in the next version of the NextGen EA. The proposed DODAF products are described below.

PURPOSE OF THE NEXTGEN ENTERPRISE ARCHITECTURE

The NextGen EA will provide the organizing logic for stakeholders to align and evaluate their respective business and technology processes in a standardized and consistent framework. Moreover, the NextGen EA will be used to help manage the complexity of developing and managing the transformational march toward NextGen, as well as aligning operational and business plans and strategies to solution implementations. The NextGen EA will enable leadership to respond to the need for rapid change to maintain the business and technical advantage necessary to meet mission requirements. The NextGen EA provides JPDO leadership, stakeholders, and partners with the requisite information and data necessary to make investment and design decisions with greater speed, precision, confidence, and clarity. These decisions will support the timely achievement of the NextGen vision and goals.

WEATHER PRODUCTS UPDATE METHODOLOGY

By collaborating with the Functional Requirements Study Group as they pursued the objectives outlined in their terms of reference, the enterprise architect team developed a more thorough understanding of the operational activities and the systems needed for providing weather information in 2025 in order to meet the needs of the NextGen air transportation community. Based on this understanding, the architect team developed architectural drawings and descriptions (products) as prescribed by the DOD Architecture Framework (DODAF) and then presented these products to the study group for review and comment. As a result of this coordination, a clear distinction was made between the operational activities performed by people and organizations, and the automated functions that will be performed by sensors and systems. These distinctions have been documented according to the DODAF methodology in the respective architectural views: Operational View and Systems View.

DESCRIPTION OF THE ENTERPRISE ARCHITECTURE TOOL

The JPDO Enterprise Architecture and Engineering Division (EAED) selected the Telelogic Corporation's System Architect© tool for capturing and retaining the NextGen EA architectural data, and for displaying the DODAF products.

The vendor's literature describes the System Architect tool as follows:

Telelogic System Architect® enables the user to build a business and enterprise architecture (EA)—a fully integrated collection of models and documents across five keys domains: strategy, business, information, systems, and technology.

Telelogic System Architect's comprehensive solution provides a shared workspace for all team members to understand how to improve the company's architecture and overall business. Telelogic System Architect promotes the following:

- Increased organizational agility
- Alignment of business processes and IT systems to business objectives
- Planning, modeling, and execution of business processes (BPM)
- Rapid, effective, and positive response to business change.

This System Architect tool requires specific skills and experience to extract the kind of information that most of the JPDO community requires; therefore, enterprise architects are the primary users of the tool. Specific reports and diagrams have been created using this tool for distribution with detailed explanations within the JPDO community. The architectural products included in Appendix E are examples of these reports. In the near future, this information will be available to the user in a more interactive medium via the JPDO NextGen Enterprise Dataset (NED) capability.

DESCRIPTION OF DODAF PRODUCTS FOR WEATHER

The following paragraphs provide descriptions, audiences, and the utility of each DODAF product proposed to update the Weather portion of the NextGen EA.

Operational Connectivity (OV-2)

Description

The Operational Node Connectivity Description is a model that illustrates the "operational nodes" (i.e., idealized places or organizations that produce or consume information) and "needlines" (i.e., highest level description of information flow) indicating that information produced at one node is needed by another node. Note that needlines do not indicate physical connectivity (i.e., depicted in the systems views); rather, they document only that a particular operational node needs information that another operational node provides.

Audience

The Operational Node Connectivity Description is intended for architects, and to provide high-level decisionmakers a more detailed view of operational nodes and information flows than is shown in the High-Level Operational Graphic (OV-1).

Utility

The operational nodes shown in the NextGen EA represent idealized places or organizations where activities are performed that require and/or produce information. The OV-2 is provided to not only represent various organizations and places where activities are performed but also provide a framework for organizing information exchanges that will be described in detail in the Operational Information Exchange Matrix (OV-3).

Operational Activity Flow (OV-5)

Description

The OV-5 is a graphical and textual description of the activities (functions or processes) performed by or within an organization, and the information associated with those activities. The OV-5 is viewed as the foundation for any architecture analysis or process improvement effort because it captures and aligns an organization's activities, relationships, associated information exchange requirements (IER), and supporting systems. The OV-5 is a foundational architecture product for the NextGen that contains data that is often used to create other architecture products essential for conveying various aspects of the community or business processes.

Audience

The OV-5 Activity Flow diagram is intended for architects, analysts, systems engineers, and systems developers.

Utility

The OV-5 Activity Flow diagram provides information that is not only useful in streamlining, combining, or eliminating activities but also helpful in eliminating redundancy. Of the greatest importance is that the OV-5 Activity Flow diagram provides a foundation for the OV-3 and OV-6c diagrams that are necessary for understanding issues of information distribution and timing—critical issues for developing a NextGen EA that will provide the performance improvements required by the NextGen Vision.

Systems Interface Diagram (SV-1)

Description

The SV-1 Systems Interface diagram depicts systems nodes (actual or idealized places where systems reside) and the systems resident at these nodes to support organizations/human roles represented by operational nodes of the OV-2. SV-1 also identifies the interfaces between systems and systems nodes. An interface (see SV-1) is a simplified abstract representation of one or more communications paths between systems nodes or between systems (including communications systems), and is usually illustrated as a straight line. SV-1 shows all interfaces of interest for architectural purposes.

Audience

The SV-1 Systems Interface diagram is intended for architects, analysts, systems engineers, and systems developers.

Utility

SV-1 identifies systems nodes and systems that support operational nodes. Some systems may have numerous interfaces. Initial versions of this product may show only key interfaces. Detailed versions may also be developed, as needed, to be used in system acquisition as part of requirements specifications and for determining system interoperabilities at a finer level of technical detail.

Systems Functionality Description (SV-4)

Description

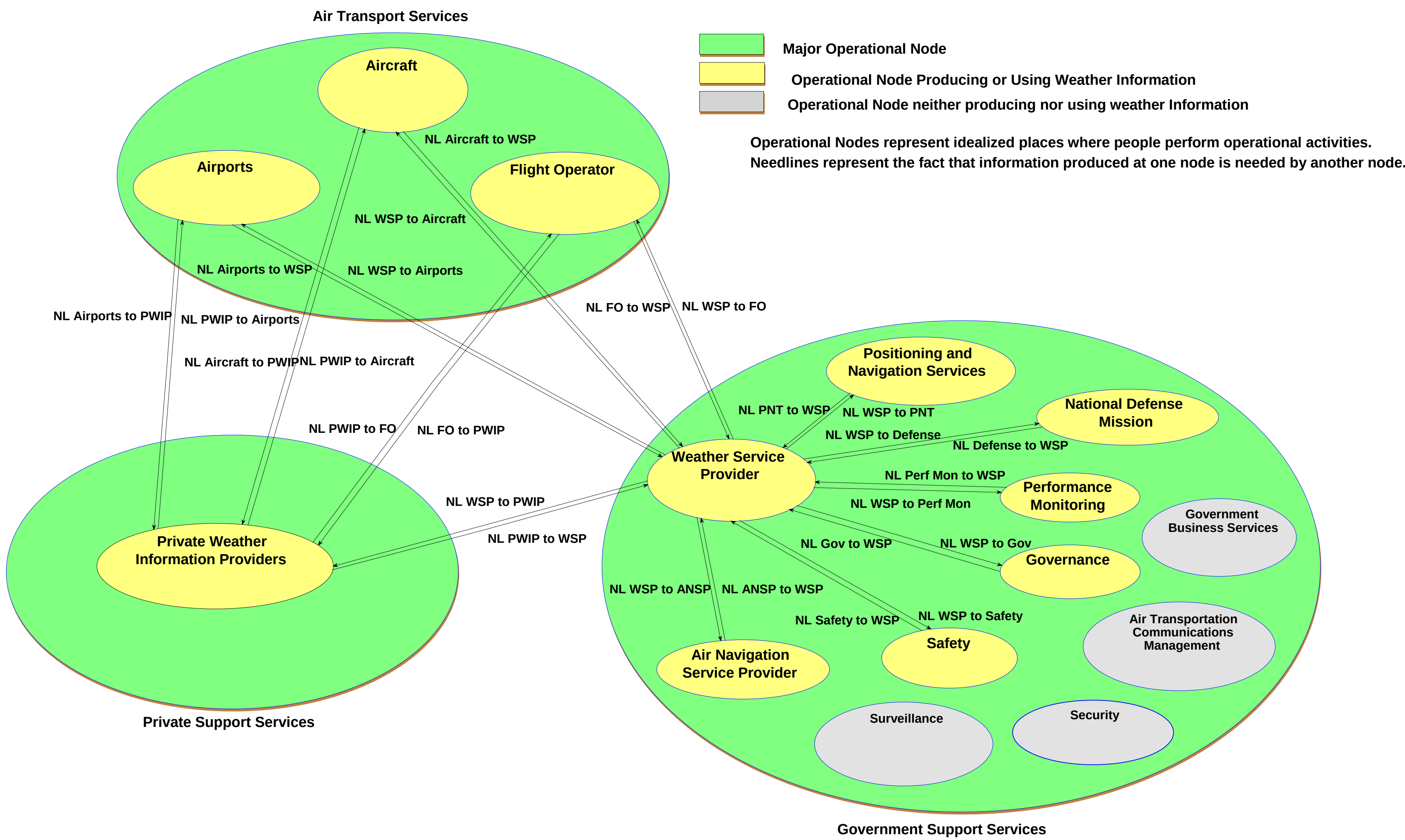
The SV-4 documents system functional hierarchies, system functions, and the system data flows between them.

Audience

The SV-4 Systems Functionality Description is intended for architects, analysts, systems engineers, and systems developers.

Utility

The primary purposes of SV-4a are to (1) develop a clear description of the necessary system data flows that are input (consumed) by and output (produced) by each system, (2) ensure that the functional connectivity is complete (i.e., that a system's required inputs are all satisfied), and (3) ensure that the functional decomposition reaches an appropriate level of detail.



Air Transport Services
Aircraft
Airports
Flight Operator
NL Aircraft to WSP
NL WSP to Aircraft
NL Airports to WSP
NL WSP to Airports
NL Airports to PWIP
NL PWIP to Airports
NL Aircraft to PWIP
NL PWIP to Aircraft
NL FO to WSP
NL WSP to FO
NL PWIP to FO
NL FO to PWIP
NL WSP to PWIP
NL PWIP to WSP
Private Weather Information Providers
Private Support Services
Positioning and Navigation Services
National Defense Mission
NL PNT to WSP
NL WSP to PNT
NL WSP to Defense
NL Defense to WSP
Weather Service Provider
NL Perf Mon to WSP
NL WSP to Perf Mon
Performance Monitoring
Government Business Services
NL Gov to WSP
NL WSP to Gov
Governance
NL WSP to ANSP
NL ANSP to WSP
NL Safety to WSP
NL WSP to Safety
Air Transportation Communications Management
Air Navigation Service Provider
Safety
Surveillance
Security
Government Support Services
Major Operational Node
Operational Node Producing or Using Weather Information
Operational Node neither producing nor using weather Information
Operational Nodes represent idealized places where people perform operational activities.
Needlines represent the fact that information produced at one node is needed by another node.

Introduction to the Weather Operational Node Connectivity Description (OV-2)

This section describes the organization and intent of the JPDO NextGen EA Weather Operational Node Connectivity Description, and provides observations relevant to the NextGen EA Objectives.

Observations Relevant to NextGen EA Objectives

The principal observation to be made from the Weather Operational Node Connectivity Description is that the weather service provider needs to send weather information to a large number of organizations that perform activities and services that are key to the ability of NextGen to achieve many of its performance goals.

A consequence of this observation is that development of unique requirements for the specific atmospheric and space conditions to be observed, forecast, and provided to these disparate users will entail significant coordination with a wide variety of disciplines, especially if one were to use the traditional approach of customizing data for each user.

Therefore, the network-enabled operations concept using a service-oriented architecture approach to distribute information will be key to providing weather information in the NextGen Enterprise. In this approach, observations and forecasts of only fundamental physical properties of the atmosphere are distributed to all users who employ their own processing power to use that fundamental information for automated decisionmaking and/or to format the information into custom human-readable weather products for presenting to human decisionmakers. Although this approach does not eliminate the need to develop data requirements from known users, it does result in more efficient communications and a more agile system that is capable of supporting an unanticipated user with minimal effort.

Description of the Weather Operational Node Connectivity Description (OV-2)

The Weather Operational Node Connectivity Description identifies *operational nodes*, defined as real or idealized “places” or organizations where *people* perform operational activities, and identifies *needlines,* defined as information flows between operational nodes at the highest level of abstraction.

The needlines shown in this OV-2 describe the fact that information created or provided at one operational node are needed or used at another operational node. These needlines create the framework under which all information and data flows will eventually be developed and documented in the Operational Information Flow Matrix (OV-3). These needlines do not describe the connectivity or path through which the information flows. Communication paths are described in the DODAF Systems View.

Assumptions

The operational nodes, organizations, and needlines shown in the OV-2 represent a reasonable estimate, based on conversations with weather SMEs from DOD, FAA, NWS, DOC, and other agencies, of what will be needed in 2025 and beyond to provide the weather information necessary to meet the NextGen vision.

Level of Detail

The OV-2 describes the operational nodes and needlines in sufficient detail to facilitate the objectives of the JPDO NextGen EA. These objectives are to identify and track the capabilities, systems, and functions that partner agencies need to develop to achieve the vision of NextGen.

Explanation of the Operational Node Connectivity Description (OV-2)

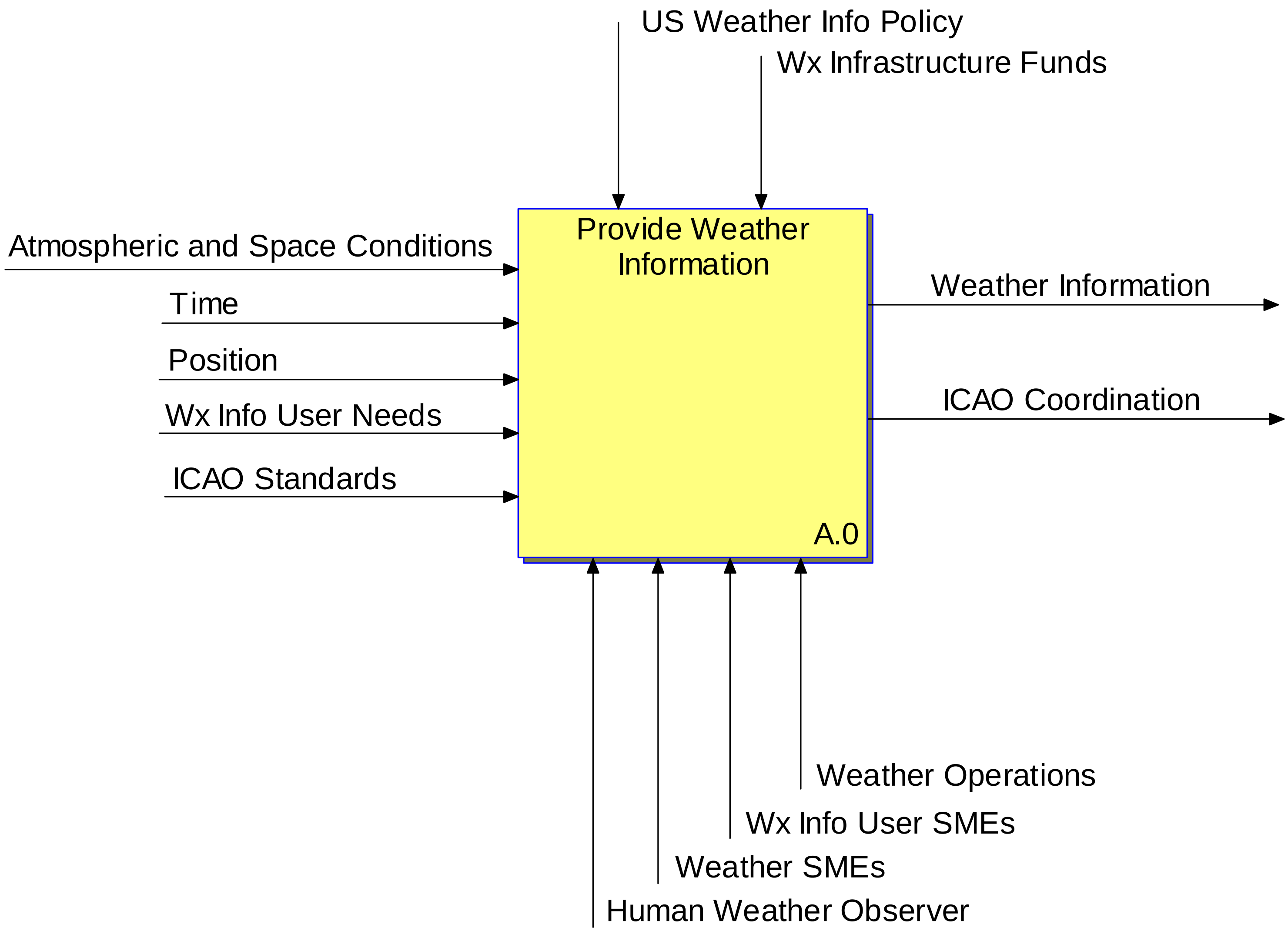
The Weather Services' Operational Node Connectivity Description organizes the operational nodes (places where people perform activities) into three major categories distinguished by the type of activity they perform:

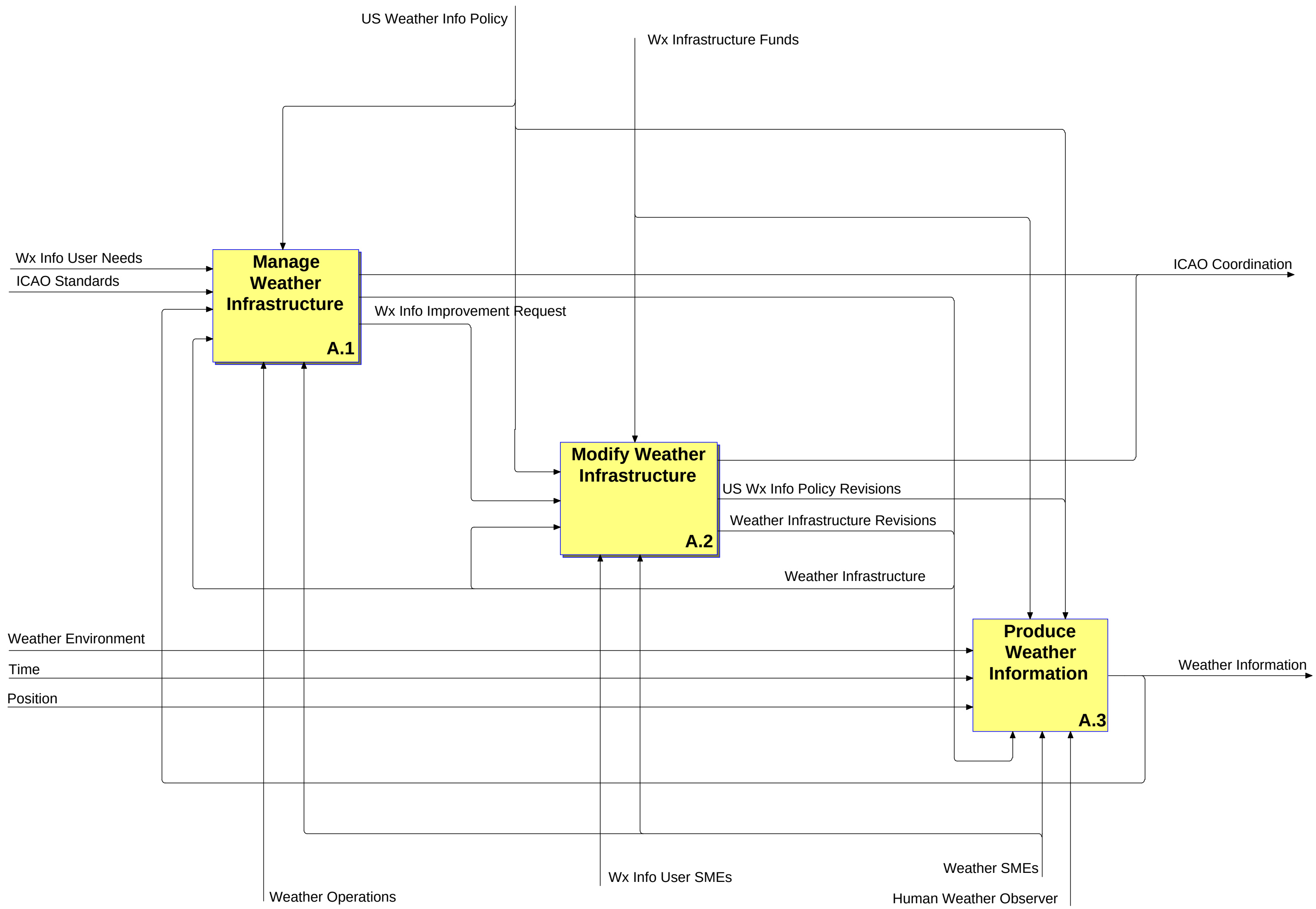
- **Air Transport Services—**comprise operational nodes that are directly involved with the movement of people and freight from origin to destination: airports, flight operators (airlines), and the aircraft themselves.
- **Government Support Services—**comprise operational nodes representing the activities of government organizations to provide services to the NextGen Enterprise. Examples are the weather service provider, position navigation and timing, and air navigation services.
- **Private Support Services—**comprise operational nodes representing the activities of private organizations to provide material and services to the NextGen Enterprise. Examples are private weather information providers, aircraft manufacturers, and avionics manufacturers. Only the operational node relevant to the weather services is shown in this OV-2 diagram.

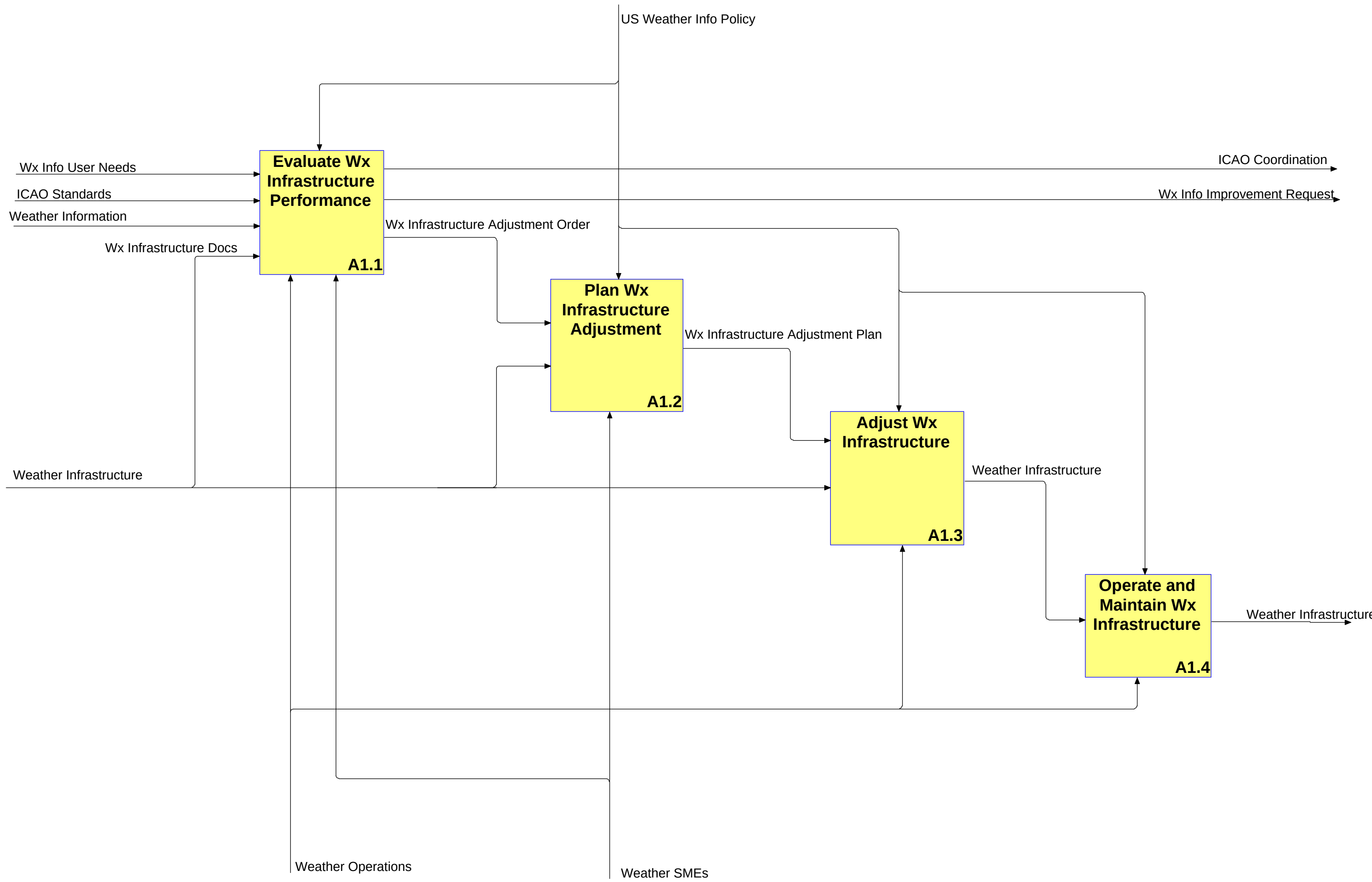
Operational nodes that produce or consume weather information are shown in yellow, whereas nodes that have not been identified as needing or producing weather information are shown in gray. Gray operational nodes are shown in the government support services area to clarify that no weather information has been identified for these operational nodes. If future research identifies such information needs, the OV-2 should be revised.

Needlines connecting the operational nodes represent the information flow produced at one node and used at another. The diagram indicates that air transport services operational nodes may obtain weather information from either the government weather service provider or private weather information provider. The fact that only the government-provided 4-D Wx SAS information can be used for air traffic management (ATM) decisions is not visible on the OV-2, but it becomes clear in the OV-5 and SV-4 diagrams.

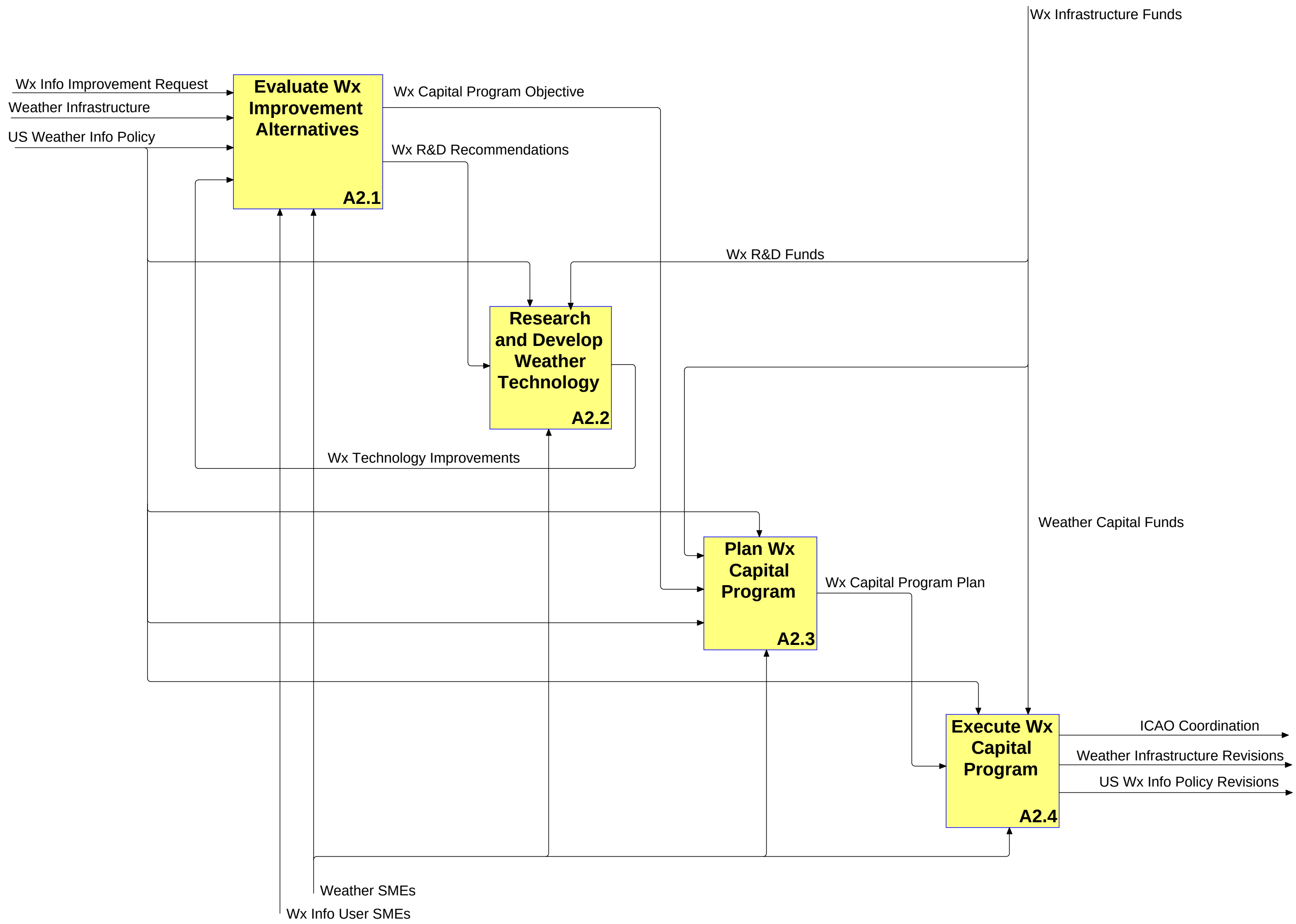
Details of operational activities performed at the operational nodes and information flows represented by needlines can be obtained from the JPDO EAED in the form of reports generated by the System Architect tool used to contain the NextGen EA architecture data.


US Weather Info Policy
Wx Infrastructure Funds
Atmospheric and Space Conditions
Time
Position
Wx Info User Needs
ICAO Standards
Provide Weather Information
A.0
Weather Information
ICAO Coordination
Weather Operations
Wx Info User SMEs
Weather SMEs
Human Weather Observer


US Weather Info Policy
Wx Infrastructure Funds
Wx Info User Needs
ICAO Standards
Manage Weather Infrastructure
A.1
ICAO Coordination
Wx Info Improvement Request
Modify Weather Infrastructure
A.2
US Wx Info Policy Revisions
Weather Infrastructure Revisions
Weather Infrastructure
Weather Environment
Time
Position
Produce Weather Information
A.3
Weather Information
Weather SMEs
Wx Info User SMEs
Weather Operations
Human Weather Observer



US Weather Info Policy
Wx Info User Needs
ICAO Standards
Weather Information
Wx Infrastructure Docs
Evaluate Wx Infrastructure Performance
A1.1
ICAO Coordination
Wx Info Improvement Request
Wx Infrastructure Adjustment Order
Plan Wx Infrastructure Adjustment
A1.2
Wx Infrastructure Adjustment Plan
Adjust Wx Infrastructure
A1.3
Weather Infrastructure
Weather Infrastructure
Operate and Maintain Wx Infrastructure
A1.4
Weather Infrastructure
Weather Operations
Weather SMEs


Wx Infrastructure Funds
Wx Info Improvement Request
Weather Infrastructure
US Weather Info Policy
Evaluate Wx Improvement Alternatives
A2.1
Wx Capital Program Objective
Wx R&D Recommendations
Wx R&D Funds
Research and Develop Weather Technology
A2.2
Wx Technology Improvements
Weather Capital Funds
Plan Wx Capital Program
A2.3
Wx Capital Program Plan
Execute Wx Capital Program
A2.4
ICAO Coordination
Weather Infrastructure Revisions
US Wx Info Policy Revisions
Weather SMEs
Wx Info User SMEs

Introduction to the Weather Operational Activity Flow Diagram (OV-5)

This section describes the organization and intent of the JPDO NextGen EA Weather Operational Activity Flow Diagram, and presents observations relevant to the NextGen EA Objectives.

Observations Relevant to NextGen EA Objectives

The principal observation from the Weather Operational Activity Flow Diagram is that operation and management of policies and infrastructure to provide NextGen Weather information should be driven by user needs. This effort will require the skills and experience of a large number of experts with a wide variety of disciplines. The OV-5 not only depicts activities to operate and manage NextGen in 2025 and beyond but also presents guidance for developing the NextGen. Weather experts alone cannot determine which operational decisions will benefit from improved weather observation and prediction. Therefore, the JPDO should encourage interdisciplinary discussions between weather SMEs and SMEs in ATM, ground operations, flight planning, and other disciplines to focus weather information improvements in those areas most beneficial to the users.

Description of the Weather Operational Activity Flow Diagram (OV-5)

The Weather Operational Activity Flow Diagram describes the activities of people supported by systems that transform information in accordance with policies or controls using the IDEF0 modeling methodology prescribed in the FIPS-183 publication.

The IDEF0 methodology shows activities as boxes with inputs entering on the left edge, outputs exiting on the right edge, supporting mechanisms (like systems or organizations) entering the bottom of the activity box, and controls (e.g., policy, laws, recipes) entering the top of the activity box. Lines flowing from one activity to another indicate that information which the source activity produces is necessary for the consuming activity to operate. The place at which the line enters the receiving activity describes how that information is used. Although a general progression of the complexity of information is shown from left to right, the diagram itself does not depict timing or sequencing. One can determine only that the output of an activity cannot be created until inputs, controls, and mechanisms have been provided.

Further, the IDEF0 methodology allows activities and information to be described in successive levels of detail using parent/child relationships to decompose a higher level of activity into a set of more detailed activities. The description of a capability begins with a single “context” diagram showing all the inputs, controls, and mechanisms from outside the capability resulting in the output to the external world.

Assumptions

The operational activities, information flows, policies, and mechanisms shown in the OV-5 represent a reasonable estimate (based on conversations with weather SMEs from JPDO partner agencies) of what will be necessary in 2025 and beyond to provide the weather information necessary to meet the NextGen goals and objectives.

Level of Detail

The OV-5 describes the operational activities and information flows in sufficient detail to facilitate the JPDO NextGen EA's objective to identify and track capabilities, systems, and functions that partner agencies need to develop to achieve the NextGen mission.

Explanation of the Weather Services Operational Activity Flow Diagram (OV-5)

The Weather Services Operational Activity Flow Diagram consists of three levels of detail.

- **First Level (context diagram)** is the highest level of abstraction. It models atmospheric and space conditions at specific locations and times being converted to weather information in accordance with U.S. Weather Information Policy, as limited by available weather infrastructure funds. It models not only that the Weather Information User Needs and ICAO standards are considered in the process of producing this information, but also that activities producing weather information coordinate with ICAO to influence their standards. The mechanisms that convert the atmospheric and space conditions into information are human weather observers, weather SMEs, weather information user SMEs, and weather operations, the organization responsible for operating and maintaining the weather infrastructure.

- **Second Level** describes these activities in greater detail. Diagram A.0 (Provide Weather Information) comprises three distinct activities: A.1 (Manage Weather Infrastructure); A.2 (Modify Weather Infrastructure); and A.3 (Produce Weather Information). The first two activities represent government organizations' work to operate, maintain, and improve sensors, systems, satellites, policies, and procedures that collect, integrate, analyze, and forecast information about the condition of the atmosphere and space. The A.3 activity uses that infrastructure and policies—along with human education, training, and experience—to produce the weather information describing the atmospheric and space conditions as a four-dimensional (the three of space, plus time) array of data values and probabilities.

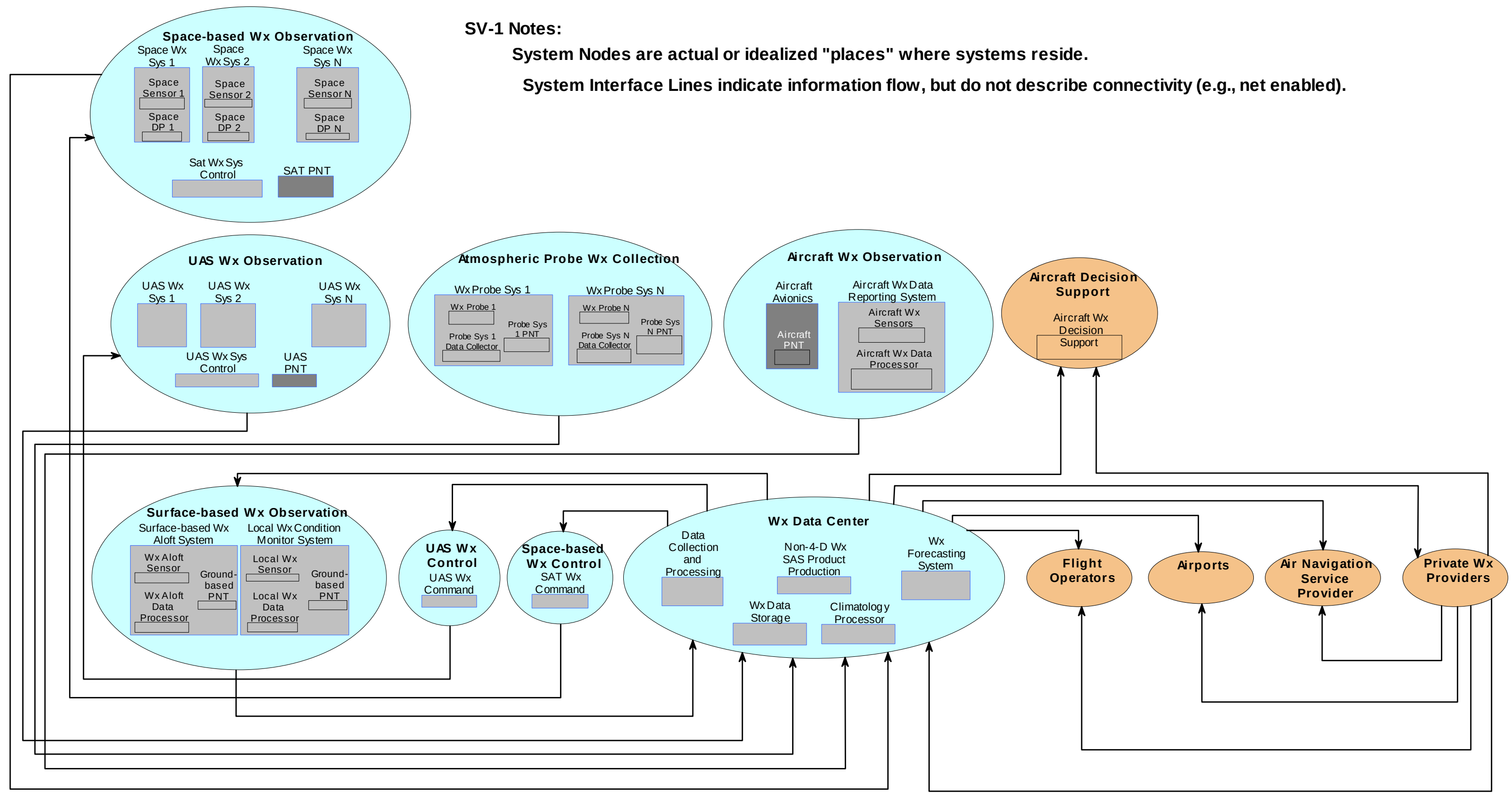
- **Third Level** describes A.1 and A.2 in greater levels of detail. The A1 drawing details the activities by which weather information is compared with user needs as the weather infrastructure is operated and maintained, to determine whether adjustments are necessary to the current infrastructure and/or policy or if the infrastructure needs major changes. It also shows how changes to ICAO standards are handled by adjustments to the infrastructure, major changes to infrastructure or policy, or continued coordination with ICAO. The A2 drawing details the activities necessary for making major changes to the infrastructure and/or U.S. Weather Information Policy. These activities include analysis of alternatives, research and development (R&D), and capital program planning and execution.

Detailed explanations of the operational activities and information flows shown in these models may be obtained from the JPDO EAED in the form of reports generated by the System Architect tool used for storing and reporting on the NextGen EA architecture data.

SV-1 Notes:

System Nodes are actual or idealized "places" where systems reside.

System Interface Lines indicate information flow, but do not describe connectivity (e.g., net enabled).



Weather Information Producing System Node.

Weather Information Producing System Entities and System Elements.

Weather Information Consuming System Node.

System or element not dedicated to weather information collection (shared).

Introduction to the Weather System Interface Diagram (SV-1)

This section describes the organization and intent of the JPDO EA Weather System Interface Description (SV-1) and provides observations relevant to the NextGen EA Objectives.

Observations Relevant to NextGen EA Objectives

An important observation concerning the systems that will comprise the NextGen Weather information capability is that currently the specific requirements of the various weather information users, in particular the NextGen Decision Oriented Tools (NDOTs), have not been determined. The current team of weather subject matter experts used the January 2005 NAS-SR-1000 as a basis to make reasoned projections, based on their experience, to estimate the specific atmospheric and space conditions, their spatial and temporal resolution, reliability, and availability that would be needed by automated Air Traffic Management systems and other weather information users. While this work represents significant progress in the development of the NextGen Weather Information Services, it will be necessary to coordinate these projections with the developers of the NDOTs and validate their needs by analysis and/or simulation. This coordination process will continue for an extensive period as the various implementing agencies move forward with the development of the envisioned NDOTs. Consequently, the NextGen EA Provide Weather Information products have been developed at a high level of abstraction, but sufficient to meet the JPDO need to identify and track partner agency development of products and systems to realize the NextGen vision.

Description of the Weather System Interface Diagram (SV-1)

This SV-1 identifies systems, system components, and their interfaces within and between system nodes. System nodes are actual or idealized places where systems reside. Systems are collections of hardware and software components that perform the functions described in the System Functionality Description, SV-4. For the JPDO NextGen EA, system nodes and systems are described in high-level, idealized terms to distinguish their general characteristics. Engineering decisions about the actual technologies that will be used to construct the systems (e.g., magnetic tape storage versus storage area networks, or massively parallel processors versus quantum computers), number, and locations of physical systems will be the subject of future programs by implementing agencies, and are thus irrelevant to the JPDO NextGen EA architecture.

Assumptions

Based on conversations with weather SMEs from DOD, FAA, NWS, DOC, and other agencies, the system nodes, systems, system components, and interfaces shown in the SV-1 represent a reasonable estimate of what will be necessary in 2025 and beyond to provide the weather information necessary for meeting the NextGen vision.

Level of Detail

The SV-1 describes the system nodes, systems, and interfaces in sufficient detail to facilitate the JPDO NextGen EA’s objectives to identify and track the capabilities, systems, and functions that partner agencies will need to develop to achieve the vision of NextGen.

Explanation of the Weather System Interface Description (SV-1)

The NextGen EA considers three regions in which atmospheric and space conditions are observed, processed, and/or used: space, atmosphere, and surface.

Weather Information Producing System Nodes

Weather information producing system nodes have been defined as follows: Space-Based Weather Observation Systems, UAS Weather Observation Systems, Atmospheric Probe Weather Collection Systems, Aircraft-Based Weather Observation Systems, Surface-Based Weather Observation Systems, and a Weather Data Center. Space-Based Weather Observation Systems, usually based on a satellite, can monitor a wide range of conditions over a large area. Atmospheric weather systems include sensors on board UAS vehicles, atmospheric probes (e.g., weather balloons, dropped probes), and sensor systems on board commercial or military aircraft. Surface-based systems include weather aloft sensors (e.g., NexRad) and local surface weather data collection systems that monitor equipment such as surface-based anemometers and thermometers. The Local Wx Condition Monitor System would also include a human/machine interface to support the collection of human-provided weather observations.

Weather Information Consuming System Nodes

Weather information consuming system nodes include Aircraft Decision Support systems and system nodes corresponding to each operational node that uses weather information (as shown on the Weather Operational Node Connectivity Description, OV-2). The Aircraft Decision Support systems use weather information for automated ATM decisions and provide custom weather products to the flight crew.

Private Weather Providers System Node

The Private Weather Providers system node is unique in that it uses government-provided weather information and provides weather information to the government weather processing systems and to system nodes corresponding to other NextGen weather information consuming operational nodes.

Remote Sensor Control System Nodes

The UAS Wx Control and Space-based Wx Control system nodes contain systems to direct and tune the respective remote sensors on these devices.

System Entities

System entities in each weather information producing system node are represented as type 1, 2, 3, etc., to distinguish among the various types of sensors employed in each region (i.e., space, airborne, and surface). Specific system names will be identified corresponding to, for example, current systems that measure atmospheric and space conditions. However, the exact nature of the NextGen systems, and the conditions they measure, will not be clarified until a better understanding of the weather information users' needs can be developed.

System Components

Each weather sensor system requires at least three components: (1) sensors to measure the meteorologic condition; (2) a PNT component to provide accurate time and location information, and (3) a data processing component to convert sensor input into measurement information in

defined units of measure, provide basic quality control (including sensor self check), and associate the measurement with the time and location.

The Weather Data Center

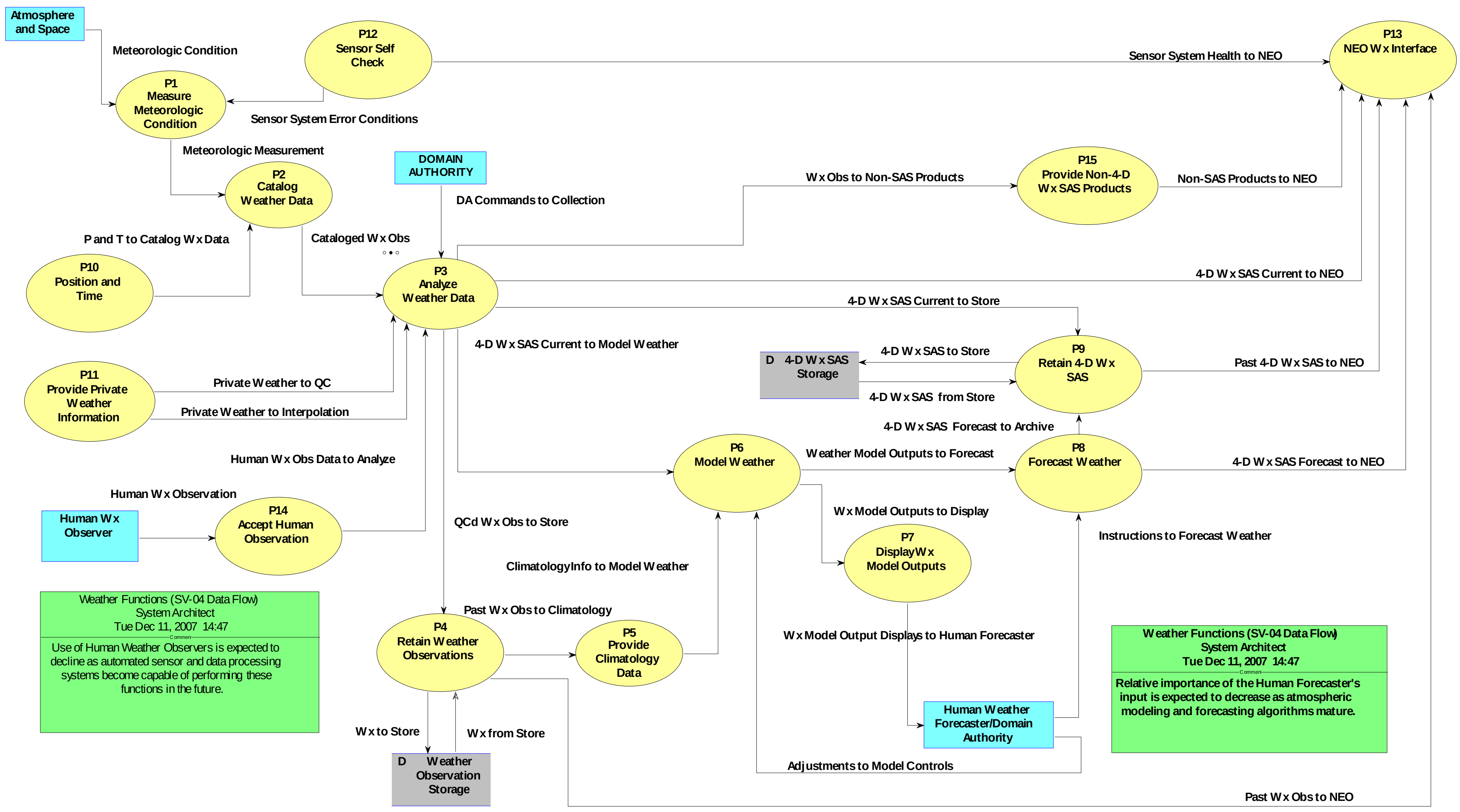
The Weather Data Center system node contains systems used to collect weather observations, process, forecast, store, and distribute weather information. The Data Collection and Processing system accepts observation data from all Wx Collection Systems; organizes the data by type, location, and time; and sends the data to storage. The observations are then subjected to quality control and used to calculate spatially interpolated values. The Wx Data Storage system stores and retrieves weather observations and interpolated values. This system should include short- and long-term storage capabilities. The Climatology Processor retrieves data from the National Wx Data Archive and calculates requested climatological information. The Wx Forecasting System accepts weather data from Wx data collection systems and climatology data from the climatology system. Currently, the Wx Forecasting System runs in two modes:

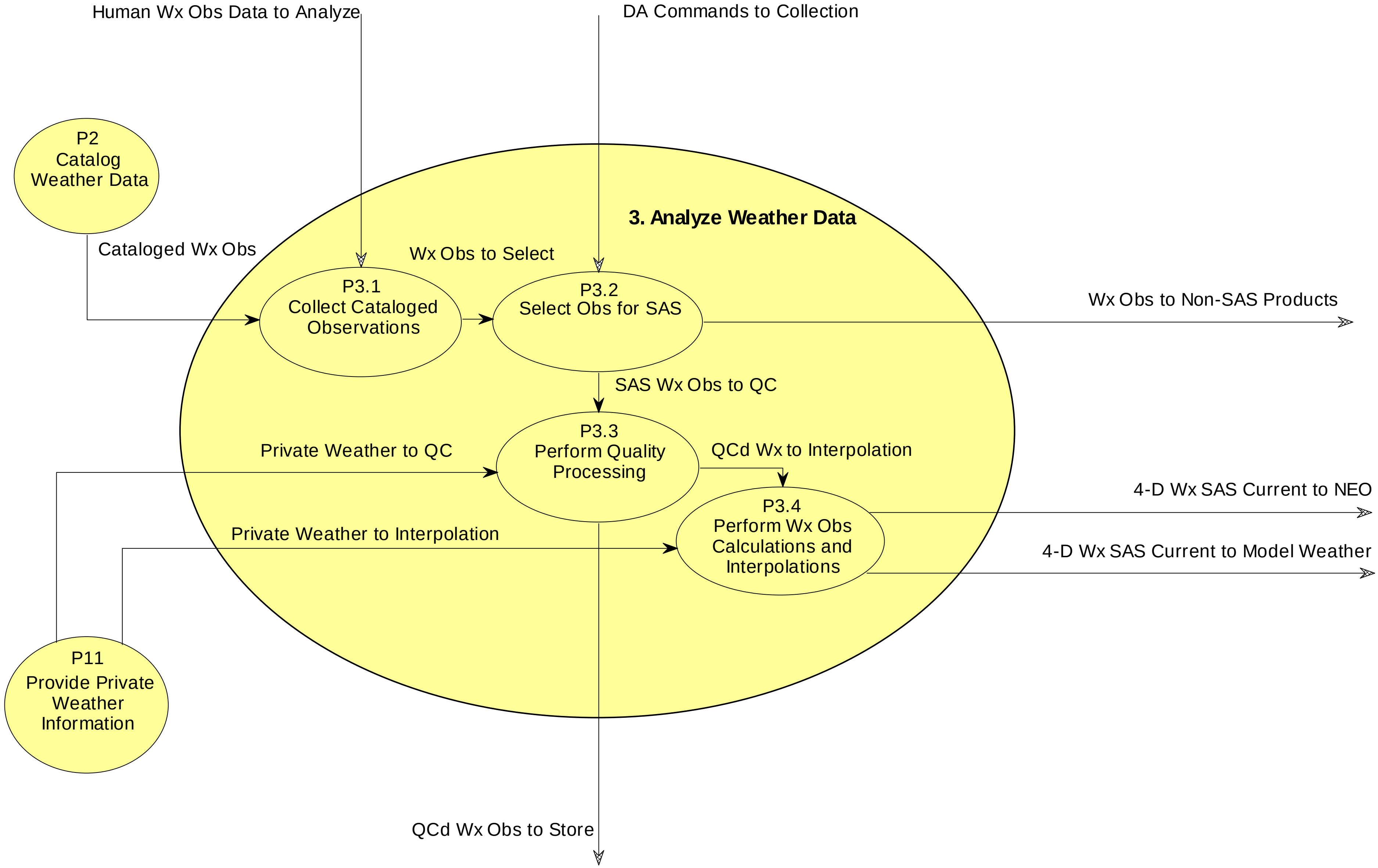
- **Human Dominant Mode—**weather models and forecasting algorithms create a set of alternative projections. These projections are presented to and studied by human forecasters who use their education, training, and experience to interpret the models in terms of comparison with observations and understanding of model strengths and weaknesses. Human forecasters produce text advisories and forecasts.
- **Automated Mode—**observational datasets are fed into a model, and algorithms produce a four-dimensional gridded analysis and forecast.

In the future, the contribution of the human-dominant mode will decrease as spatial and time resolution requirements increase to meet NextGen requirements. The eventual complete automation of the forecasting process, which is expected to be necessary to meet the spatial and temporal requirements of NextGen, will require the advancement of forecasting technology well beyond current levels.

A Note Regarding System Ownership

Note that the SV-1 neither specifies nor implies ownership of the system nodes or systems. It is likely that the weather observation systems on satellites and UASs, and even surface-based observation systems, are simply components on platforms designed, built, and operated for missions other than weather data collection. Even the Aircraft Weather Observations systems node is a minor component on a platform (the aircraft) whose primary mission is to transport people and/or freight.


Atmosphere and Space
Meteorologic Condition
P12 Sensor Self Check
Sensor System Health to NEO
P13 NEO Wx Interface
P1 Measure Meteorologic Condition
Sensor System Error Conditions
Meteorologic Measurement
P2 Catalog Weather Data
DOMAIN AUTHORITY
DA Commands to Collection
Wx Obs to Non-SAS Products
P15 Provide Non-4-D Wx SAS Products
Non-SAS Products to NEO
P and T to Catalog Wx Data
Cataloged Wx Obs
P10 Position and Time
P3 Analyze Weather Data
4-D Wx SAS Current to NEO
4-D Wx SAS Current to Store
4-D Wx SAS Current to Model Weather
D 4-D Wx SAS Storage
4-D Wx SAS to Store
4-D Wx SAS from Store
P9 Retain 4-D Wx SAS
Past 4-D Wx SAS to NEO
P11 Provide Private Weather Information
Private Weather to QC
Private Weather to Interpolation
4-D Wx SAS Forecast to Archive
Human Wx Obs Data to Analyze
P6 Model Weather
Weather Model Outputs to Forecast
P8 Forecast Weather
4-D Wx SAS Forecast to NEO
Human Wx Observation
Human Wx Observer
P14 Accept Human Observation
QCd Wx Obs to Store
Wx Model Outputs to Display
P7 Display Wx Model Outputs
Instructions to Forecast Weather
ClimatologyInfo to Model Weather
Weather Functions (SV-04 Data Flow)
System Architect
Tue Dec 11, 2007 14:47
Use of Human Weather Observers is expected to decline as automated sensor and data processing systems become capable of performing these functions in the future.
Past Wx Obs to Climatology
P4 Retain Weather Observations
P5 Provide Climatology Data
Wx Model Output Displays to Human Forecaster
Weather Functions (SV-04 Data Flow)
System Architect
Tue Dec 11, 2007 14:47
Relative importance of the Human Forecaster's input is expected to decrease as atmospheric modeling and forecasting algorithms mature.
Wx to Store
Wx from Store
Human Weather Forecaster/Domain Authority
D Weather Observation Storage
Adjustments to Model Controls
Past Wx Obs to NEO


Human Wx Obs Data to Analyze
DA Commands to Collection
P2
Catalog
Weather Data
3. Analyze Weather Data
Cataloged Wx Obs
Wx Obs to Select
P3.1
Collect Cataloged
Observations
P3.2
Select Obs for SAS
Wx Obs to Non-SAS Products
SAS Wx Obs to QC
P3.3
Perform Quality
Processing
Private Weather to QC
QCd Wx to Interpolation
4-D Wx SAS Current to NEO
P3.4
Perform Wx Obs
Calculations and
Interpolations
Private Weather to Interpolation
4-D Wx SAS Current to Model Weather
P11
Provide Private
Weather
Information
QCd Wx Obs to Store

Introduction to the Weather Systems Functionality Description (SV-4)

This section describes the organization and intent of the JPDO EA Weather System Function Flow Diagram (SV-4) and presents observations relevant to the NextGen EA Objectives.

Observations Relevant to NextGen EA Objectives

The System Function Flow Diagram identifies three places at which human expertise and input is required to perform functions necessary for providing weather information to NextGen:

- **Human Weather Observers** provide measurements of atmospheric conditions from noninterfaced sensors and observations of gross atmospheric conditions (e.g., thunderstorms, tornadoes, water spouts).
- **Domain Authority** draws on his/her education and experience to select sources of observations for inclusion in developing the 4-D Wx Single Authoritative Source for Air Traffic Management (4-D Wx SAS).
- **Weather Forecaster** draws on his/her education and experience to adjust inputs to various weather models and to forecasting algorithms to develop the forecast portion of the 4-D Wx SAS.

In these human activities, automation can potentially increase the speed, efficiency, reliability, and consistency of the weather observation and forecasting process; therefore, these activities should have increased R&D to achieve the NextGen Vision.

Description of the Weather Systems Functionality Description (SV-4)

This SV-4 describes the automated functions and system data exchanges necessary for converting sensor- and human-based observations of atmospheric and space weather conditions into weather information in the form of data that can be readily distributed to automated decision support tools anywhere in the NextGen Enterprise.

Assumptions

The system functions and information flows shown in the SV-4 represent a reasonable estimate of those functions that will be necessary in 2025 and beyond to provide the weather information necessary for meeting users' needs.

Level of Detail

The SV-4 describes the functions in sufficient detail to facilitate the objective of the JPDO NextGen EA: identify and track the capabilities, systems, and functions that partner agencies need to develop to achieve the vision of NextGen.

Explanation of the Weather Systems Functionality Description (SV-4)

The NextGen EA considers three types of weather information sources: sensor measurements, human observations, and private weather information.

- **Sensor Measurements.** The sensor measurement data flow begins with the external atmosphere and/or space conditions presenting a meteorologic condition to a

measurement function, P1, which converts the condition into a numerical value in a defined units scale. The functional data flow includes a sensor self-check function (P12) that indicates whether a malfunction is detected in the system that performs the measurement. This indication is included in the meteorologic measurement data exchange.

To be useful in weather information processing, any measurement of an atmospheric condition must be coupled with the time and three-dimensional (3-D) location where the measurement is taken. Therefore, a position and time function, P10, is necessary to provide this associated data. The catalog weather data function, P2, couples the meteorologic condition measurement with its associated position and time data.

- **Human Observations**. Human observation data flow begins with a human observer who determines that a particular meteorologic condition is occurring at a particular location and time. The human observer provides values (type and extent of weather phenomenon, 3-D location, and time) to the NextGen via the Accept Human Weather Observation function that helps the human observer provide complete and accurate data. This function converts the human observations into normalized units so that they can be coordinated with others in subsequent automated processing. As the graphic note on the SV-4 diagram states, use of human weather observation is expected to decline in terms of a percentage of all collected weather data; however, these functions are included in the NextGen weather architecture, with the expectation that human observations will not be entirely eliminated in the NextGen.
- **Private Weather Information.** The NextGen government-provided weather information services accept weather information from private weather vendors. This SV-4 includes the Provide Private Weather Information function, P11, to convert privately collected observations of meteorologic conditions into a format suitable for integration with sensor measurements and human observations. Currently, private weather information is used in providing quality control and extrapolation of weather conditions between directly measured or observed points. Under current contractual agreements, that information cannot be directly sent to NextGen weather information users.

The Analyze Weather Data function, P3, creates the current conditions portion of the 4-D Wx SAS using observations from all three information sources, and direction from the Domain Authority. It also outputs collected weather observations to the Provide Non-4-D Wx SAS Products function, P16. Analyze Weather Data, P3, consists of the following four subfunctions:

- **Collect Cataloged Observations, P3.1** organizes the cataloged weather observations from P2, Catalog Weather Data, and the human-provided weather observations from P14, Accept Human Observation, by type, location, and time. This function also performs any necessary unit conversions to an internal standard set of units for each type of atmospheric or space condition.
- **Select Obs for 4-D Wx SAS, P3.2** implements the Domain Authority's direction to select observations from only specific sources for inclusion in developing the 4-D Wx SAS. All observations are provided to function P15, Provide Non-4-D Wx SAS Products.

- **Perform Quality Processing, P3.3** evaluates observations for reasonability and rejects observations that do not meet the reasonability criteria. Reasonability can be based on absolute value of the observation (e.g., temperature much greater than historical record for that location) and on spatial or temporal trends (e.g., d (temp)/dt or d (temp)/dp greater than a threshold). Private weather information can also be considered in the quality processing.

- **Perform Wx Obs Calculations and Interpolations, P3.4** calculates certain values (e.g., time averages and meteorologic parameters) that can be calculated from direct observations (RH from temp and dew point), and estimates (interpolates) values of atmospheric conditions between spatial and temporal sample points. Private Wx data is used for Interpolation and/or QC only. Currently, Private Wx observations (e.g., lightning data) cannot be part of the 4-D Wx SAS. The output of the Perform Wx Obs Calculations and Interpolations is the Current values portion of the 4-D-Wx SAS.

The forecast portion of the 4-D Wx SAS is developed from the current conditions portion by functions P5, Provide Climatology Data; P6, Model Weather; P7, Display Wx Model Outputs; and P8, Forecast Weather, under the direction of the Human Weather Forecaster, as follows:

- **Provide Climatology Data, P5** analyzes past weather observations over temporal and spatial regions to determine climatological trends of the atmosphere in geographic regions of interest. These analyses are provided to the Model Weather function, P6.

- **Model Weather, P6** uses multiple weather models and forecasting algorithms to create a number of possible forecasts for the various atmospheric parameters of interest. These models are adjusted and combined by the human forecaster to provide outputs that are consistent with his or her training and experience.

- **Display Wx Model Outputs, P7** provides human-readable displays of the weather models and forecasting algorithms to the human weather forecaster. The forecaster uses these displays to make further adjustments to the weather model controls.

- **Forecast Weather, P8** accepts multiple weather model outputs from the Model Weather function and instructions from a human forecaster for combining those outputs to create an official weather forecast for ATM.

The following functions store information for later use by other functions or other users throughout the NextGen Enterprise. Note that the SV-4 storage functions do not consider the length of time that data must be retained. Such engineering considerations would influence the types of systems that would be used to implement the storage function, which is the province of the System Interface Diagram (SV-1) and the System Performance Parameters Matrix (SV-7).

- Retain Weather Observations, P4, manages the database of stored weather observations and makes them available to P5, Provide Climatology Data, and to users in the NextGen Enterprise through the Network-Enabled Operations Weather Interface, P13.

- Retain 4-D Wx SAS, P9, accepts the 4-D Wx SAS current conditions information from P3, Analyze Weather Data, and the forecast portion of the 4-D Wx SAS from the

Forecast Weather function, P8, safely stores it, and retrieves the information upon request.

Provide Non-4-D Wx SAS Products represents the totality of functions that create custom weather products from the weather observations for distribution to authorized users throughout the NextGen Enterprise. Note that ATM decision-oriented tools are not authorized to receive these products because they are restricted to the use of 4-D Wx SAS. Details of the functions necessary to provide the Non-4-D Wx SAS products are not shown in this architectural product because they are not considered necessary for JPDO coordination.

NEO Wx Interface, P13, represents the interface to the communications systems that transport weather information to authorized users throughout the NextGen Enterprise.

APPENDIX F. LEXICON

The Lexicon Subteam was responsible for developing Appendix F. This lexicon is divided into two parts—verbs and nouns—and defines terms used in the 4-D Wx Single Authoritative Source (SAS) functions. The Lexicon Subteam used authoritative reference sources for definitions, including the following: NextGen ConOps v2.0 and Enterprise Architecture; NOAA glossaries; American Meteorological Society Glossary; Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) Federal Meteorological handbooks; FAA Aeronautical Information Manual (AIM); Pilot/Controller Glossary (PCG); NASA glossaries; DOD glossaries; and other online dictionaries and sources.

VERBS

Term	Definition
Accept	To receive or contain.
Acquire	To come into the possession of something concrete or abstract.
Analyze	To examine carefully and in detail so as to identify causes, key factors, possible results, and so on.
Archive	To place or store in an archive; see definition under Nouns.
Assimilate	To become absorbed or incorporated into the system.
Average	To find an average value for (a variable quantity); reduce to a mean.
Backup	To make copies of weather information to protect against loss of needed data.
Calculate	To determine or ascertain by mathematical methods; compute.
Catalog	To accept measurements of atmospheric conditions and associate the time and location of the observation with the measurement data.
Collect	To bring together in a group or mass; gather.
Compare	To examine in order to note the similarities or differences of.
Derive	To arrive at by reasoning; deduce or infer.
Detect	To discover or ascertain the existence, presence, or fact of.
Determine	To establish or ascertain definitely, as after consideration, investigation, or calculation.
Forecast	To estimate or calculate in advance, especially to predict (weather conditions) by analysis of meteorological data.
Fuse	To unite or blend into a whole, as if by melting together.
Generate	To produce something according to an algorithm or program or set of rules.
Impact	To affect aviation in either a positive (e.g., tail wind) or negative (e.g., hazardous weather) manner.
Ingest (Weather)	To take in weather data (or product) for the purpose of integration and/or processing.
Initialize	To set (as a computer program counter) to a starting position, value, or configuration.
Integrate	To make into a whole by bringing all parts together; unify. To make part of a larger unit.
Interpolate	To estimate mathematically the value of a weather parameter in between two known values on a grid.
Interpret	To determine or ascertain something in understandable terms from that which is not intuitively obvious (e.g., possible limit on who can perform—for weather, a meteorologist).
Issue	To put forth or distribute, usually officially.
Manage	To handle, direct, govern, or control in action or use.
Measure	To ascertain the extent, dimensions, quantity, capacity, etc., of, especially by comparison with a standard.
Merge	To combine or unite into a single enterprise, organization, body, etc.
Observe	To watch, view, or note for a scientific, official, or other special purpose.
Observe (Detect)	To evaluate or measure, by human or automated means, one or more meteorological parameters (e.g., temperature, wind speed/direction, visibility, precipitation) that describe the state of the atmosphere either at the Earth's surface or aloft.
Overlay	To superimpose one or more images over a common background.
Perform	To carry out; execute; do.
Predict	To determine 4-D state of an atmospheric parameter(s).

Term	Definition
Prepare	To manufacture, compound, or compose.
Present	To convey information.
Process	To handle (e.g., papers, records) by systematically organizing them, recording or making notations on them, following up with appropriate action, or the like.
Protect	To secure or preserve against encroachment, infringement, restriction, or violation.
Provide	To make available; furnish.
Publish	To issue (as, a product) for public distribution or access. The act of publishing often includes the addition or updating of an entry in a data directory or catalog that is accessible to the user community. Such directory or catalog entries publicize the availability of data to subscribers or other potential users, and occasionally even instruct them on where the product can be acquired.
Quality Control (QC)	To use a system for verifying and maintaining a desired level of quality in a product or process by careful planning, use of proper equipment, continued inspection, and corrective action as required.
Quantify	To express as a number or measure or quantity.
Receive	To have delivered or brought to one.
Refine	To improve the result by increasing product resolution or accuracy, or increasing product detail.
Reformat	To reshape, resize, or alter the form or appearance of data or product.
Request	To inquire for (information).
Request/Reply	To ask for an unscheduled weather product (or information) and receive it in a timely manner.
Respond	To act in return or in answer.
Retain	To store or archive for future use. (Note: see definition of “store” or “archive” for amount of time retained.)
Retrieve	To locate and read (data) from storage.
Run	To process, refine, manufacture, or subject to an analysis or treatment.
Select	To choose or make a choice.
Standardize	To establish agreed-on criteria or values governing the accepted use of data or information.
Store	To copy (data) into memory or onto a storage device (short trend as opposed to archiving).
Store (Weather)	To retain for short time (< 2 days) for purpose of enhancing interpretation (e.g., weather image looping, trending).
Subscribe	To establish an ongoing agreement whereby the user (subscriber) receives one copy of each edition or version of one or more data products, or receives one version of a data product at some agreed-on frequency.
Sum	To combine into an aggregate or total.
Support	To maintain (e.g., a person, family, establishment, institution) by supplying with things necessary to existence.
Tailor	To adapt product or information output for a particular use.
Update	To incorporate new or more accurate information in, for example, a database, program, or procedure.
Verify	To determine the accuracy of a weather forecast by comparing the predicted weather with the observed weather of the forecast period.

NOUNS AND OTHER TERMS

Term	Definition
4-Dimensional State (4-D) (Weather)	In the context of weather, the three dimensions of space, plus that of time (forecast value of a parameter in the future).
4-Dimensional Weather Data Cube (4-D Wx Data Cube)	All unclassified weather information used directly and indirectly for aviation decisions. It contains all relevant aviation weather information formed from the collection of observations, automated gridded products, models, climatological data, and human forecasters from public and private sources. The 4-D Wx Data Cube is composed of text products, graphic products, and machine-readable products. It contains products in the public domain and products that are proprietary. It also contains domestic and nondomestic weather information. The production of the 4-D Wx Data Cube and its utilization by NAS users' applications operationally is the essence of NextGen weather capabilities.
4-Dimensional Weather Single Authoritative Source (4-D Wx SAS)	Single, standardized source of a parameter of weather information used for making air transportation management decisions. The source is designated by the domain authority as the authoritative source so that service providers and users will access common weather information for making air traffic management (ATM) decisions. Each type of information can have its own authoritative source. For example, information taken directly from a numerical model may be the authoritative source for forecast winds and temperatures, whereas airport wind and temperature sensors may be the authoritative sources for current terminal winds and temperatures. The authoritative source provides the information used by default. Users *other than ATM* personnel may occasionally decide to use information other than that from the authoritative source (e.g., an airline may use a forecast from its own meteorology department); however, in so doing, they are aware of the authoritative source and they are opting to override and deviate from the default. The 4-D Wx SAS data are in the public domain and available to all users.
Accuracy	Ability of a measurement to match the actual value of the quantity being measured.
Advisory (Weather)	Abbreviated plain-language product or a statement from a federal actor concerning the occurrence or expected occurrence of weather phenomena that may be hazardous or that may affect the safety of aircraft operations.
Air Traffic Management (ATM)	Dynamic, integrated management of air traffic and airspace—safely, economically, and efficiently—through the provision of facilities and seamless services in collaboration with all parties.
Airport Wind	Wind sensor designated by airport manager as the "official" source of wind for the airport from the multiple wind sources that may be available on the airport.
Algorithm	Mathematical step or procedure that either calculates directly (e.g., wind averaging) a representative value for a weather parameter; or, in conjunction with other algorithms (e.g., part of weather model), calculates (contributes to) a derived value for a weather parameter.
Analysis	Projection of the state of the atmosphere (or any system) as known from a finite set of imperfect, irregularly distributed observations onto a regular grid, or to represent the atmospheric state by the amplitude of standard mathematical functions.
Archive	Permanent record of surface weather reports and related data used to establish a climatological record and for the purposes of accident investigation.
Atmosphere	Envelope of air surrounding the Earth whose chemical properties, dynamic motions, and physical processes constitute meteorology.
Auroral Zone	Approximately circular region around the two geomagnetic poles within which a maximum of auroral activity exists. The region lies about 10 to 15 degrees of geomagnetic latitudes from the geomagnetic poles. The auroral zone broadens and extends equatorward during intense auroral displays.
Availability	Readiness for use; that is, degree to which a system, subsystem, or equipment is operable and in a committable state for a mission or purpose. The proportion of time a system is in a functioning condition. Typical availability objectives are specified either in decimal fractions, such as 0.9998, or sometimes in a logarithmic unit called "nines," which corresponds roughly to a number of nines following the decimal point, such as "five nines" for 0.99999 availabilty.
Average	Value obtained by dividing the sum of a set of quantities by the number of quantities in the set. Also called arithmetic mean.
Backup	Provision of designated weather data and information when the principal method of production and/or delivery is not available.

Term	Definition
Beginning Times of Thunderstorm	Beginning of a thunderstorm, reported as the earliest time: (1) thunder is heard; (2) lightning is observed at the station when the local noise level is sufficient to prevent hearing thunder; or (3) lightning is detected by an automated sensor.
Beginning Times of Wind Shear/Microburst	Beginning of a wind shear/microburst, reported as the earliest time wind shear/microburst is detected by an automated sensor.
Blowing Dust	Dust picked up locally from the surface of the Earth and blown about in clouds or sheets, reducing the reported horizontal visibility to less than 7 statute miles.
Blowing Sand	Sand particles picked up from the surface of the Earth by the wind to moderate heights above the ground, reducing the reported horizontal visibility to less than 7 statute miles.
Blowing Snow	Snow lifted from the surface of the Earth by the wind to a height of 6 feet or more above the ground and blown about in such quantities that the reported horizontal visibility is reduced to less than 7 miles.
Blowing Spray	Water droplets torn by the wind from a body of water, generally from the crests of waves, and carried up into the air in such quantities that they reduce the reported horizontal visibility to less than 7 statute miles.
Calm Wind (Surface)	Absence of apparent motion of the air. In the Beaufort wind scale, this condition is reported when smoke is observed to rise vertically, or when the surface of the sea is smooth and mirror-like. The National Weather Service (NWS) reports a wind as calm when it is determined to have a speed of less than 3 knots.
Clear Air Turbulence (CAT)	Turbulence encountered in air where no clouds are present. This term is commonly applied to high-level turbulence associated with wind shear. CAT is often encountered in the vicinity of the jet stream.
Climatology	Thorough, quantitative descriptions of climate, particularly with reference to tables and charts that show characteristic values of weather parameters at a station or over an area. In this paper, we often refer to aeronautical climatology, which is the application of the data and techniques of climatology to aviation meteorological problems.
Cloud Ceiling	Lowest layer aloft reported as broken or overcast; or vertical visibility into an indefinite ceiling.
Cloud Layer	Array of clouds, not necessarily all of the same type, with bases at approximately the same level. It may be either continuous or composed of detached elements.
Cloud Layer Height	Height of the bases of each reported layer of clouds and/or obscuration; or vertical visibility into an indefinite ceiling.
Cloud Type	Cloud form that is identified according to the *World Meteorological Organization (WMO) International Cloud Atlas*.
Common Operating Picture (COP)	Single identical collection of relevant information shared by more than one command. A COP facilitates collaborative planning and helps all echelons to achieve situational awareness.
Common Weather Picture (CWP)	Consistent, relevant weather COP enabled by the 4-D Wx SAS for air traffic decisionmakers.
Compression Winds	Related to wind change in speed/direction with height over/near airports; vertical wind profile.
Consistency	Coherent representation of the physical atmosphere.
Critical Service	Function or service which, if lost, would prevent the National Airspace System (NAS) from exercising safe separation and control over aircraft.
D Region	Daytime layer of the Earth's ionosphere about 50 to 90 km in altitude.
Data (Generic)	Facts, concepts, or instructions represented in a formalized manner suitable for communication, interpretation, or processing by human or automated means.
Data (Model)	Output from a weather computer model (e.g., analyses and forecasts of weather parameters).
Data (Weather)	Data (weather) acquired directly from a sensor (or observed by a human) that has had minimal processing, only formatting or QC; can be in human-readable (text) form or can require additional processing (e.g., radar imagery, gridded data) to be useful.
Data (Weather) (Historical)	Archived weather data that relates characteristic values for meteorological parameters with respect to a particular time (day or hour), place, and season, as opposed to (and distinct from) climatology, which represents an average over time.
Data (Weather) (Trend)	Recent weather data (observations) or weather products arranged/displayed chronologically for viewing to readily discern patterns or behavior

Term	Definition
Decision Support Tool (DST)	Tool that incorporates observations, forecasts, model/algorithm data, and climatology, including surface observations and weather aloft, to allow full integration of weather into traffic flow decisionmaking.
Delay	The state of occurring later or slower than expected or desired.
Dewpoint Temperature	Temperature to which a given parcel of air must be cooled at constant pressure and constant water-vapor content for saturation to occur.
Diagnosis	See entry entitled “Analysis.”
Digital	Expressed in numerical form, especially for use by a computer.
Direction of Precipitation Movement	Direction toward which precipitation is moving.
Direction of Thunderstorm Movement	Direction toward which a thunderstorm is moving.
Direction of Tornado Movement	Direction toward which a tornado is moving.
Disk	Visible surface of the sun (or any heavenly body) projected against the sky.
Domain Authority	Lead office or position sanctioned to define the authoritative weather parameter data sources for a given domain, such as the continental United States (CONUS) atmospheric, European atmospheric, or space domains. To prevent potentially conflicting weather information from being provided to various decisionmakers (within the ATM community), the domain authority defines and implements clear operating rules for determining the data source to be used for a given time, location, and application. The domain authority will implement operating rules, which could change with time (e.g., seasonally or during phases of the solar cycle) and with model upgrades. Examples include selecting the numerical model or ensemble with the best performance statistics for a given location and season. The end goal is to ensure that all decisionmakers who request weather information from the 4-D Wx SAS for a similar location, time, and application receive consistent information.
Drizzle	Fairly uniform precipitation composed exclusively of fine drops (diameter less than 0.02 inch or 0.5 mm) very close together. Drizzle appears to float while following air current, although unlike fog droplets, it falls to the ground.
Duration of Precipitation	Period of time in which continuous precipitation is observed, or occurs at a specific point or within a specific area.
Dust Storm	Severe weather condition characterized by strong winds and dust-filled air over an extensive area.
Efficiency	Ratio of the effective or useful output to the total input in any system.
Electron	Lightweight particle, carrying a negative electric charge and found in all atoms. Electrons can be energized or even torn off atoms by light and by collisions and are responsible for most electric phenomena and light emission in solid matter and in plasmas.
Ending Times of Thunderstorm	Ending of a thunderstorm, reported as 15 minutes after the last occurrence of any of the following criteria: (1) thunder is heard; (2) lightning is observed at the station when the local noise level is sufficient to prevent hearing thunder; or (3) lightning is detected by an automated sensor.
Essential Service	Function or service that, if lost, would reduce the capability of the NAS to exercise safe separation and control over aircraft.
F Region	Upper layer of the ionosphere, approximately 120 to 1,500 km in altitude. The F region is subdivided into the F1 and F2 regions. The F2 region is the densest and peaks at altitudes between 200 and 600 km. The F1 region is a smaller peak in electron density, which forms at lower altitudes in the daytime.
Flare	Sudden eruption of energy on the solar disk, lasting from minutes to hours and from which radiation and particles are emitted.
Flexibility	Ability to change (or be changed) to fit changed circumstances.
Flight Information Region	Airspace of defined dimensions within which flight information service and alerting service are provided. Also called FIR.
Flux	Rate of flow of a physical quantity through a reference surface.
Fog	Visible aggregate of minute water particles (droplets) that are based at the Earth’s surface and that reduce horizontal visibility to less than 5/8 statute mile; unlike drizzle, it does not fall to the ground.
Fog Bank	Fairly well-defined mass of fog observed in the distance, most commonly at sea.

Term	Definition
Forecast	Prediction of the future state of the atmosphere, with specific reference to one or more associated meteorological parameters.
Forecast (Deterministic)	Forecast governed by and predictable in terms of definite laws (e.g., dynamic equations), with the notion that there is at any instant exactly one future outcome (forecast). A deterministic forecast might be based on one specific outcome of a numerical weather prediction model (versus a probabilistic forecast, which might be based on an ensemble member set).
Forecast (Probabilistic)	Forecast arrived at using stochastic processes and represented in probabilistic terms, such as in a probability density function (i.e., a statistical function that shows how the density of possible observations or forecasts in a population is distributed) or a probability distribution function (i.e., a mathematical description of a random variable in terms of its admissible values and the probability associated, in an appropriate sense, with each value). In the field of numerical weather prediction, probabilistic forecasts are often arrived at based on evaluations or analyses of model ensembles.
Forecast Confidence	Confidence in a forecast, which is sometimes inferred or provided by ensemble forecasts, where a model run, in which members diverge, often corresponds to a lower forecast certainty, whereas member convergence implies or indicates a higher forecast certainty.
Freezing Drizzle	Drizzle that freezes upon impact with the ground or other exposed objects.
Freezing Fog	Fog whose droplets freeze upon contact with exposed objects and form a coating of rime and/or glaze.
Freezing Level	Commonly, and in aviation terminology, lowest altitude in the atmosphere, over a given location, at which the air temperature is 0°C; height of the 0°C constant-temperature surface.
Freezing Precipitation	Any form of precipitation that freezes upon impact and forms a glaze on the ground or exposed objects.
Freezing Rain	Rain that freezes upon impact and forms a glaze on the ground or exposed objects.
Frequency of Lightning Groundstrokes	Rate of recurrence of lightning discharges over a specified period of time.
Function (System Engineering)	Characteristic action or activity that must be performed to achieve a desired objective or stakeholder need.
Funnel Cloud	Violent, rotating column of air that does not touch the surface, usually appended to a cumulonimbus cloud.
Geomagnetic Storm	Worldwide disturbance of the Earth's magnetic field, distinct from regular diurnal variations.
Geo-Referenced	Defined or specified in physical space. Related (e.g., via one or more coordinate systems or map projections) to a position relative to the Earth. In a geographic information system (GIS), a system for capturing, storing, analyzing, and managing data and associated attributes that are spatially referenced to the Earth. The association of geophysical data (e.g., image data or grid points) to some geographic control framework (e.g., specifying the location by its latitude, longitude, and altitude above mean sea level).
Geosynchronous	Any equatorial satellite with an orbital velocity equal to the rotational velocity of the Earth. The net effect is that the satellite is virtually motionless with respect to an observer on the ground.
Global Positioning System (GPS) Pseudo-Range	Each GPS satellite transmits an accurate position and time signal. The user's receiver measures the time delay for the signal to reach the receiver, which is the direct measure of the apparent range ("pseudo-range") to the satellite.
Graupel	Heavily rimed snow particles, often called snow pellets; often indistinguishable from very small soft hail, except for the size convention that hail must have a diameter greater than 5 mm.
Groundstroke Lightning Discharge	Series of electrical processes usually occurring within less than 1 second by which charge is transferred along a discharge channel between electric charge centers of opposite sign within a thundercloud (in-cloud flash), between a cloud charge center and the Earth's surface (cloud-to-ground flash or ground-to-cloud discharge), between two different clouds (inter-cloud or cloud-to-cloud discharge), or between a cloud charge and the air (air discharge).
Hail	Precipitation in the form of small balls or other pieces of ice falling separately or frozen together in irregular lumps.
Haze	Suspension in the air of extremely small, dry particles invisible to the naked eye and sufficiently numerous to give the air an opalescent appearance.

Term	Definition
High-Frequency Communications	Communications system that uses high frequencies (HF) between 3 and 30 Megahertz (MHz) for air-to-ground voice communication in overseas operations.
Hourly Accumulation of Liquid Precipitation	Amount of liquid precipitation that falls over a period of 1 hour.
Ice Accretion Rate	Relative speed of progress or change of a layer of ice (icing) as it builds up on solid objects that are exposed to freezing precipitation or to supercooled fog or cloud droplets.
Ice Crystals	More or less regular periodic array of water atoms, molecules, or ions, usually forming a solid.
Ice Pellet	Type of precipitation consisting of transparent or translucent pellets of ice (5 mm or less in diameter).
Icing	Formation of ice, rime, or hoarfrost on an aircraft.
Impact	Effect of weather on NAS safety or capacity.
Input (Weather)	Weather data (usually formatted) “ingested” by an algorithm or computer model.
Intensity	1. In general, expresses the rate of transfer per unit area of some condition or physical quantity, such as rainfall, electromagnetic energy, or sound. 2. Radiant intensity. Radiant power per unit solid angle; in SI units, W sr^{-1}. 3. In synoptic meteorology, the general strength of flow around an individual cyclone or anticyclone (most often applied to the former). This concept is commonly used in terms of a process, “intensification,” or descriptively, as an “intense low.”
Ionosphere	Region of the Earth’s upper atmosphere containing a small percentage of free electrons and ions produced by photo-ionization of the constituents of the atmosphere by solar ultraviolet radiation at very short wavelengths (< 1000 angstroms). The ionosphere significantly influences radiowave propagation of frequencies less than about 30 MHz.
Ionospheric Storm	Disturbance in the F Region of the ionosphere that occurs in connection with geomagnetic activity.
K Index	3-hourly quasi-logarithmic local index of geomagnetic activity relative to an assumed quiet-day curve for the recording site. The range is from 0 to 9. The K index measures the deviation of the most disturbed horizontal component.
Kp Index	3-hourly planetary geomagnetic index of activity generated in Gottingen, Germany, based on the K Index from 12 or 13 stations distributed worldwide.
Latency	In information processing and dissemination, the time required for an event to occur. This event might be attributed to database access times, computer processing times, and network or communication lags (e.g., time taken for a data packet to be sent by an application and received by another application). Such events might include, for example— 1. The time elapsed between the moment a user requests a product and the moment the product is delivered to that user’s system. 2. The time elapsed between the moment a new product is available on some central server and the moment that a subscriber of that product receives a complete copy of that product. 3. The time elapsed between the moment a central database is updated and the moment a user is informed that new information is available. 4. The time elapsed between the moment an observation is taken by a sensor system (e.g., a surface observation or a weather radar) and the moment that observation is available to a user.
Lightning	Luminous phenomenon accompanying a sudden electrical discharge. See entries entitled “Lightning, Cloud-to-Air”; “Lightning, Cloud-to-Cloud”; “Lightning, Cloud-to-Ground”; and “Lightning, In-Cloud.”
Lightning Potential	Possibility of lightning.
Lightning, Cloud-to-Air	Streaks of lightning that pass from a cloud to the air but do not strike the ground.
Lightning, Cloud-to-Cloud	Streaks of lightning reaching from one cloud to another.
Lightning, Cloud-to-Ground	Lightning occurring between a cloud and the ground.
Lightning, In-Cloud	Lightning occurring within a cloud.
Liquid Equivalent of Solid Precipitation	Liquid content of solid precipitation that has accumulated on the ground (snow depth). The accumulation may consist of snow, ice formed by freezing precipitation, freezing liquid precipitation, or ice formed by the refreezing of melted snow.
Liquid Precipitation	Any form of precipitation that does not fall as frozen precipitation and does not freeze upon impact.

Term	Definition
Low Drifting Sand	Sand that is raised by the wind to less than 6 feet above the ground; visibility is not reduced below 7 statute miles at eye level, although objects below this level may be veiled or hidden by the sand particles moving nearly horizontal to the ground.
Low Drifting Snow	Snow that is raised by the wind to less than 6 feet above the ground; visibility is not reduced below 7 statute miles at eye level, although objects below this level may be veiled or hidden by the particles moving nearly horizontal to the ground.
Low-Earth Orbit	Orbital altitude range (500 to 2000 km above the surface of the Earth).
Low-Level Wind Shear	Wind shear not associated with convective activity from the surface up to and including 2,000 feet above ground level. Wind shear is a potentially hazardous problem for aircraft preparing for approach to, or for take-off from, aerodromes, when the fluctuation is airspeed is 10 knots or more.
Machine-Readable	Suitable for feeding directly into a computer. Information encoded in a form that can be read (i.e., scanned/sensed) by a machine/computer and interpreted by the machine's hardware and/or software. Common machine-readable data storage and data transmission technologies are processing waveforms, optical character recognition (OCR), and barcodes.
Maximum Altitude of Volcanic Ash	Highest vertical position of a volcanic ash plume.
Maximum Surface Temperature	Highest temperature during a specified time period at the surface.
Mega (Million) Electron Volt (MeV)	Unit of energy used to describe the total energy carried by a particle or photon.
Mesocyclone	Storm-scale region of rotation, typically about 2 to 6 miles wide, often found in the right rear flank of a supercell (or often on the eastern, or front, flank of a high precipitation storm). The circulation of a mesocyclone covers an area much larger than the tornado that may develop within it. Properly used, mesocyclone is a radar term that is defined as a rotation signature appearing on Doppler radar that meets specific criteria for magnitude, vertical depth, and duration. It will appear as a yellow solid circle on Doppler velocity products. Therefore, a mesocyclone should not be considered a visually observable phenomenon (although visual evidence of rotation, such as curved inflow bands, may imply the presence of a mesocyclone).
Meta Tag	Commonly used to describe the contents of a Web page. May be either description or keyword meta tag. Most search engines use this data when adding pages to their search index.
Metadata	Structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource. Metadata is often called "data about data."
Microburst	Convective downdraft with an affected outflow area less than 2½ miles wide and peak winds lasting less than 5 minutes. Microbursts may induce dangerous horizontal/vertical wind shears, which can adversely affect aircraft performance and cause property damage.
Minimum Altitude of Volcanic Ash Layers Where the Volcanic Ash Is Most Concentrated	Lowest vertical position of the portion of the volcanic ash plume with the largest concentration of particulates.
Mist	Suspension in the air consisting of an aggregate of microscopic water droplets or wet hygroscopic particles (of diameter not less than 0.5 mm or 0.02 in.), reducing the visibility at the Earth's surface to not less than 1 km or 5/8 mile. The term "mist" is used in weather reports when such obscurity exists, the associated visibility is 1,000 meters or more, and the corresponding relative humidity is 95 percent or more, but is generally less than 100%. These hydrometeors or water particles, form a thin grayish veil that covers the landscape. The "mist" also reduces visibility, but to a lesser extent than fog.
Model (Weather)	Description or analogy used to help visualize something that cannot be observed directly (generic). For Weather—See entry entitled "Weather Model."
National Airspace System (NAS)	Common network of U.S. airspace; air navigation facilities, equipment and services, airports, or landing areas; aeronautical charts, information, and services; rules, regulations, and procedures; technical information; and manpower and material. Included are system components shared jointly with the military.
Need	User stated capability necessary to accomplish a task or mission.

Term	Definition
Net-Enabled Information (NEI)	Information network that makes information available, securable, and usable in real time to distribute decisionmaking. Information may be pushed to known users and is available to be pulled by other users, including users perhaps not previously identified as having a need for the information.
Network-Enabled Operations (NEO)	Decision support and other applications using NEI for information transfer and retrieval.
Nowcast	Description of current weather and short-term weather forecasts varying from minutes to 1 to 2 hours
Obscurations	Any phenomenon in the atmosphere, other than precipitation, that reduces the horizontal visibility in the atmosphere.
Obstructions to Vision (OTV)	In U.S. weather observing practice, one of a class of atmospheric phenomena, other than the weather class of phenomena, that might reduce horizontal visibility at the Earth's surface.
Ocean Wave and Swell Direction	True direction in degrees from which primary and secondary swell waves are coming. Use swell wave height to distinguish primary from secondary swells. Swells are waves that have traveled into an area of observation after being generated by wind in other areas.
Ocean Wave and Swell Height	Vertical distance between trough and crest for wind waves and swells in units of meters or feet. Primary swells are higher than secondary waves.
Ocean Wave and Swell Speed	Wave (swell) period is the time between the passage of two successive wave (swell) crests past a fixed point.
Operational Decisionmaker	Within FAA, an air traffic controller, traffic management specialist, or flight service specialist. Outside the FAA, a pilot or dispatcher.
Output	Products or information from a computer (e.g., weather model, algorithm) generated for dissemination.
Partial Fog	Substantial part of a station is covered by fog, while the remainder is clear of fog.
Patches (of) Fog	Fog patches that randomly cover a station.
Peak Wind (Peak Gust)	In U.S. weather observing practice, the highest "instantaneous" wind speed recorded at a station during a specified period, usually the 24-hour observational day. Therefore, a peak gust need not be a true gust of wind. The peak gust is typically expressed in terms of a speed (in units of knots or mph) and direction (e.g., degrees from north, or categorical direction such as NE, E, SSE). In addition, a specific time of day may be noted with the peak wind.
Plasma	Any ionized gas; that is, any gas containing ions and electrons.
Position	Position represents the location of an object in space. Position can be represented via coordinates (e.g., xyz, for East-West, North-South, and altitude) or via various GIS representations (e.g., shape files).
Precipitation	Any of the forms of aqueous particles—whether liquid water, ice, or mixed content—that fall from the atmosphere and reach the Earth's surface. The amount of precipitation is usually expressed in millimeters or inches of liquid water or frozen substance depth, sometimes over a specified period of time. Liquid precipitation is usually measured in a fixed rain gauge, and small amounts of dew, frost, rime, etc., may be included in the total. Frozen precipitation may be measured by the accumulated depth on the ground. The rate of precipitation deposition or accumulation is sometimes qualified as intermittent, light, moderate, or heavy. Intermittent precipitation (e.g., showers) is a precipitation event of short duration and/or fluctuating intensity, as from convective or cumuliform clouds. Before deposition on the Earth's surface (i.e., while still in the atmosphere), precipitation is a subset of the broader term "hydrometeor." A distinguishing characteristic between precipitation and nonprecipitation hydrometeors is that the latter (e.g., small liquid fog droplets) are found suspended in the atmosphere with such low terminal velocities that their fall or deposition rate is small relative to the (chiefly) horizontal winds and other currents that primarily dictate particle movement. Precipitation can exist and can be measured at the Earth's surface or aloft.
Predictability	Extent to which future states of a system may be predicted based on knowledge of current and past states of the system. Because knowledge of the system's past and current states is often imperfect, as are models that use this knowledge to produce a prediction, predictability is inherently limited. Even with arbitrarily accurate models and observations, limits to the predictability of a physical system may still exist.
Pressure Falling Rapidly	Decrease in station pressure at a rate of 0.06 inch of mercury or more per hour, which totals 0.02 inch or more at the time of the observation.

Term	Definition
Pressure Rising Rapidly	Increase in station pressure at a rate of 0.06 inch of mercury or more per hour, which totals 0.02 inch or more at the time of the observation.
Prevailing Visibility	Greatest horizontal visibility that is equaled or surpassed throughout half of the horizon circle; it need not be a continuous half. The prevailing visibility is considered representative of conditions at the station.
Private Weather Providers	Business organizations that supply weather information, generally for a profit. Such organizations are outside the public (government) and voluntary sectors. Weather information from such private weather providers may occasionally have restrictions on access, use, and redistribution.
Process (Weather)	Series of actions or functions (e.g., data assimilation, analysis, and product generation).
Product (Weather)	Output tailored for use by a meteorologist or a decisionmaker; may not require meteorological training to interpret.
Proton Event	By definition, the measurement of at least 10 protons/sq.cm/sec/steradian at energies greater than 10 MeV.
Proximity of TS Precipitation to Airport or Spaceport	Direction (as in degrees from north and distance from airport to TS precipitation. Direction may be represented as degrees from north or categorically (e.g., NE, ENE, E).
Radio Event	Flares with centimetric bursts and/or definite ionospheric event (Sudden Ionospheric Disturbance).
Rain	Precipitation, in the form of drops larger than 0.02 inch (0.5 mm) or smaller, which in contrast to a drizzle, are widely separated. For automated stations, precipitation that remains in the liquid state upon impact with the ground or other exposed objects. Drizzle is distinguished from rain in that the droplets in a drizzle are less than 0.5mm in diameter, are more numerous per unit volume, and generally reduce visibility much more than light rain.
Rain Intensity	Rate of rainfall, usually expressed in unit of depth per unit of time (e.g., millimeters or inches per hour). For the purposes of observation, the intensity of rainfall at any given time and place may be expressed categorically as (1) "light," the rate of fall varying between a trace and 0.25 cm (0.10 in.) per hour, the maximum rate of fall being no more than 0.025 cm (0.01 in.) in 6 minutes; (2) "moderate," from 0.26 to 0.76 cm (0.11 to 0.30 in.) per hour, the maximum rate of fall being no more than 0.076 cm (0.03 in.) in 6 minutes; and (3) "heavy," the rate of fall being more than 0.76 cm (0.30 in.) per hour or more than 0.076 cm (0.03 in.) in 6 minutes. Rainfall intensity can be observed or forecast at the surface or aloft (although rainfall aloft is better represented categorically rather than in depth/time units).
Rain Shower	Qualification used to describe rain that is characterized by relative suddenness of onset or termination, or by rapid changes in intensity, and usually accompanied by rapid changes in the appearance of the sky. Rain showers often originate from convective/cumuliform clouds. In METAR code, rain showers are coded SHRA.
Refresh Rate	Frequency at which a product is renewed (i.e., replaced with a more recent version). The refresh rate (commonly, the "vertical refresh rate," "vertical scan rate" for cathode ray tubes [CRT]) is the number of times in a second that display hardware draws the data it is being given.
Region(s) of Supercooled Liquid Droplets	Atmospheric volume that contains supercooled liquid droplets. This volume may be defined by its location centroid and radial dimensions, including altitude above surface or sea level.
Regions of In-Flight Icing	Atmospheric volume in which in-flight icing may be likely due to one or more concentrations of supercooled liquid droplets. This volume may be defined by its location centroid and radial dimensions, including altitude above surface or sea level. Research or further technical consultation is needed to define thresholds.
Regions Where High-Energy (> 100 MeV) Solar Radiation Poses Biological Risk to: Crew Pregnant passengers or crew Equipment (e.g., navigation and communications)	Atmospheric volume where high-energy solar radiation is or may be likely. This is influenced by factors such as latitude, altitude, solar-cycle stage, and (to internal components and humans) aircraft construction materials. This volume may be defined by its location centroid and radial dimensions, including altitude above surface or sea level. Research or further technical consultation is needed to define thresholds.

Term	Definition
Regions Where Solar Activity Significantly Degrades Air Traffic Control (ATC) Communications	Atmospheric volume and/or surface areas where solar activity degrades ATC communications. This is influenced by factors such as latitude, altitude, solar-cycle stage, solar storms, communications mechanism or frequency, and (to internal components and humans) aircraft construction materials. This volume may be defined by its location centroid and radial dimensions, including altitude above surface or sea level. Research or further technical consultation needed to define thresholds.
Regions Where Solar Activity Significantly Degrades Navigation	Atmospheric volume and/or surface area where solar activity degrades navigation. This is influenced by factors such as latitude, altitude, solar-cycle stage, solar storms, and (to internal components and humans) aircraft construction materials. This volume may be defined by its location centroid and radial dimensions, including altitude above surface or sea level. Research or further technical consultation needed to define thresholds.
Regions Where Solar Activity Will Impact Power Grids	Surface area where solar activity will impact power grids. This is influenced by factors such as latitude, altitude, solar-cycle stage, solar storms, and (to internal components and humans) aircraft construction materials. This region may be defined by its central location, radial dimensions, latitude/longitude coordinates (polygon vertices)or a GIS shape file. Research or further technical consultation is needed to define thresholds.
Regions Where Solar Radiation Poses a Biological Hazard (> 100MeV) to Airliner Crews and Passengers	Atmospheric volume where high-energy solar radiation poses a biological hazard. This is influenced by factors such as latitude, altitude, solar-cycle stage, and (to internal components and humans) aircraft construction materials. This volume may be defined by its location centroid and radial dimensions, including altitude above surface or sea level. Further research or further technical consultation is needed to refine threshold.
Representative	Serving as a typical or characteristic example.
Requirement (Weather)	Weather need that has undergone a validation process, such a requirement to support a FAA decisionmaker function.
Resolution	1. Degree to which nearly equal values of a quantity can be discriminated. 2. Smallest measurable change in a quantity. 3. Least value of a measured quantity that can be distinguished. 4. Formal inference rule permitting computer programs to reason logically.
Resolution (Spatial)	Degree to which nearly equal values of a quantity can be discriminated in space. The smallest measurable change in a quantity. The least value of a measured quantity that can be distinguished. For gridded products, the distance between two grid points (e.g., in the horizontal and vertical dimensions).
Resolution (Time)	Degree to which nearly equal values of a quantity can be discriminated in time. The smallest measurable change in a quantity. The least value of a measured quantity that can be distinguished. For gridded products, the temporal difference (e.g., in seconds or hours) between two successive grids.
Risk (in relation to vulnerability, threat probability, and impact)	Concept that denotes a potential negative impact to an asset or some characteristic of value that may arise from some present process or future event. The probability of a known or plausible harm or loss. The possibility of an event occurring that will have an impact on the achievement of objectives. Risk is measured in terms of impact and likelihood. For large information technology systems, there are potentially numerous risks. A few examples of risk areas are security threats (e.g., system intrusion, malicious software, denial of service), physical or facilities risks (e.g., related to power, environmental controls, physical access), maintainability risks (e.g., availability of hardware equipment replacement parts, software maintenance or operator support), and business/administrative risks (e.g., organizational and management support for system functions).
Routine Weather	Category of individual and combined atmospheric phenomena that must be drawn on to describe the local atmospheric conditions at a specific time. Such routine weather phenomena may not directly affect aviation operations.
Runway Visibility	Visibility along an identified runway, determined from a specified point on the runway with the observer facing in the same direction as a pilot using the runway.
Runway Wind	Horizontal wind, specified by speed (e.g., distance/time units such as m/sec) and direction (e.g., degrees from north or categorically, NE, NNE, E, ESE), observed or forecast at a specified point on or near an airport runway. Prevailing wind (speed and direction) measurement/observation or forecasts can be supplemented with gust information, degrees of variability, recent directional shifts, and current or expected threshold exceedances (e.g., high winds).

Term	Definition
RVR	Runway visual range (RVR) represents the horizontal distance a pilot can see down a runway from the approach end. The RVR is the range over which the pilot of an aircraft on the center line of a runway can see the runway surface markings or the lights delineating the runway or identifying its center line. RVR is typically instrument derived (e.g., by means of a transmissometer installed near the end of the runway), but can alternatively be determined by an observer located at the end of the runway, facing in the direction of landing. This measurement can be nearly instantaneous (typically, a very short duration average) or it can be averaged over a number of intervals. This computation can be performed by the sensor or by downstream processing. RVR information may be encoded in METARs and other observations, but only if the visibility is less than or equal to 1 statute mile and/or the RVR is less than or equal to 6,000 feet.
RVR (Average)	RVR that is the average of RVR measurements made at intervals (e.g., 1, 3, 5, or 10 minutes, or even 1 hour). RVR also can be near instantaneous, as stated in entry entitled “RVR.”
RVR 10-Minute Average	RVR (as defined above) averaged over 10 minutes.
RVR at Mid-Point	RVR (as defined above), except as defined at the runway midpoint. Thus, it is the runway visibility (e.g., in feet) that the pilot should have at the runway midpoint. For example, if the RVR at midpoint is 2,000, that means that when the aircraft is at the midpoint of the runway, the pilot should be able to see the runway 2,000 feet ahead.
RVR at Rollout	RVR (as defined above), except as defined at the runway rollout point. Thus, it is the runway visibility (e.g., in feet) that the pilot should have at the runway rollout point (i.e., entry point of runway for takeoff).
RVR at Touchdown	RVR (as defined above), except as defined at the runway touchdown point. Thus, it is the runway visibility (e.g., in feet) that the pilot should have when the aircraft first touches down on the runway following descent.
Sandstorm	Event during which a strong wind is carrying sand through the air. The diameter of most of the particles ranges from 0.08 to 1 mm. In contrast to a dust storm, most of the sand particles in a sandstorm are confined to the lowest 3.5 m (10 ft), rarely rise more than 15 m (50 ft) above the ground, and proceed mainly in a series of leaps (saltation). Sandstorms are best developed in desert regions where there is loose sand, often in dunes, without much admixture of dust. Sandstorms are attributed to strong winds caused or enhanced by surface heating, tend to form during the day, and tend to die out at night. According to U.S. observing procedures, a sandstorm is reported if the blowing sand reduces the horizontal visibility to less than 1 km, but not less than 500 m. A severe sandstorm is reported if the blowing sand reduces the horizontal visibility to less than 500 m.
Sea Level Pressure	Atmospheric pressure at mean sea level either directly measured or, most commonly, empirically determined from the observed station pressure. In regions in which the Earth’s surface is above sea level, it is standard observational practice to reduce the observed surface pressure to the value that would exist at a point at sea level directly below if air of a temperature corresponding to that actually present at the surface were present all the way down to sea level. In practice, the mean temperature for the preceding 12 hours is used, rather than the current temperature. This “reduction of pressure to sea level” is responsible for many anomalies in the pressure field in mountainous areas on the surface synoptic chart.
Sea State	Description of the properties of sea surface waves at a given time and place. This might be given in terms of the wave spectrum, or more simply in terms of the significant wave height and some measure of the wave period.
Seamless	Consistent and coherent.
Sector Visibility	Visibility in a specified direction that represents at least a 45-degree arc of the horizon circle. The average observed or computed visibility (distance units) in a sector, where a sector is any portion of the area surrounding the station out as far as the horizon. When the visibility surrounding the station is not uniformly equal in all directions and the difference is operationally significant, then each area with a different visibility is designated a sector. The size of the sector, extending in a pie-slice out from the observation point, is as large or small as required to describe the area affected by the different visibility, but must be limited to 1/8 (45°) of the horizon circle. Sector visibility is commonly used at air stations that have lakes, rivers, or swamps nearby, which favor fog development. For example, visibility in fog over a swamp area could be 3 miles, whereas visibility in haze in the remainder of the area could be 7 miles.

Term	Definition
Service Provider	For FAA, an air traffic controller, traffic management specialist, or flight service specialist; also meteorological personnel providing aviation support (government or vendor).
Shallow Fog	Fog in which the visibility at 6 feet above ground level is 5/8 statute mile or more, and the apparent visibility in the fog layer is less than 5/8 statute mile.
Signal Conditioning	Treatment of a signal return from a sensor or instrument to ensure that only acceptable values are passed through for processing.
Significant Weather	In aviation weather, the occurrence or expected occurrence of specified en route weather phenomena that might affect the operation of aircraft.
Sky Condition	Sky's appearance, which may be evaluated automatically by instrument or manually with or without instruments. Sky condition parameters are as follows: A. *Sky Cover*—Amount of the celestial dome hidden by clouds and/or obscurations. B. *Summation Layer Amount*—Categorization of the amount of sky cover at and below each reported layer. C. *Layer Height*—Height of the bases of each reported layer of clouds and/or obscurations; or the vertical visibility into an indefinite ceiling. D. *Ceiling*—Lowest layer aloft reported as broken or overcast; or the vertical visibility into an indefinite ceiling. E. *Type of Clouds*—Variety of clouds present.
Sky Cover	Parameter in the "sky condition" category, defined as the amount of the celestial dome hidden by clouds and/or obscurations. In measuring or detecting sky cover, any clouds or obscurations detected from the observing location are included. Other considerations when measuring or expressing sky cover: *A. Clear Skies*—No clouds or obscurations are observed or detected from the point of observation. B. *Layer Amounts*—The amount of sky cover for each layer shall be the eighths (or oktas) of sky cover attributable to clouds or obscurations (e.g., smoke, haze, fog) in the layer being evaluated. C. *Summation Layer Amount*—The sky cover summation amount for any given layer is the sum of the sky cover for the layer being evaluated plus the sky cover of all lower layers, including obscurations. Portions of layers aloft detected through lower layers aloft shall not increase the summation amount of the higher layer. No layer can have a summation amount greater than 8/8. D. *Variable Amounts of Sky Cover*—The sky cover shall be considered variable if it varies by one or more reportable values (FEW, SCT, BKN, or OVC) during the period it is being evaluated.
Sky Cover Stratification	Separation of sky cover into layers with each layer containing clouds and/or obscurations (e.g., smoke, haze, fog) with bases at about the same height.
Slant Range Visibility	Visibility along the line of sight between two points at differing altitudes, most often used to refer specifically to the visibility along the line of sight between an airborne aircraft and the touchdown end of a runway of interest. This sight line is sometimes restricted to mean the sight line over the nose of the airplane, and thus is sometimes referred to as approach visibility.
Small Hail	Class of precipitation called graupel. Similar to snow pellets. Opaque grains of ice, usually round or conical, with diameters in the range of approximately 0.08 to 0.25 inch (2 to 6 mm).
Smoke	Suspension in the air of small particles produced by combustion. Sometimes used to refer to certain types of fog (e.g., sea smoke). Can be observed and reported at the surface or aloft.
Snow	Type of frozen (or mostly frozen) precipitation composed of white or translucent ice crystals, chiefly in complex branch hexagonal form and often agglomerated into snowflakes. Also refers to a broad class of precipitation that includes snow, snow grains, and other snow-containing hybrid precipitation forms (e.g., pellets of snow encased in ice). A "present weather" type to describe it as current precipitation, blowing, drifting, and so on. Can be observed and reported at the surface or aloft.
Snow Depth	Vertical height of frozen precipitation on the ground, as measured over a horizontal or near-horizontal surface. For this purpose, frozen precipitation includes ice pellets, glaze, hail, any combination of these, and sheet ice formed directly or indirectly from precipitation. Units of length are used (in U.S., inches, cm or mm) to report snow depth. Snow depth can be measured and reported corresponding to various time periods, such as total depth on ground, storm total, new/added depth since prior report, new/added depth over a specified time period (e.g., 1 hour). When the snow is not uniformly distributed, snow depth is measured by taking an average of multiple measurements.

Term	Definition
Snow Grains	Form of frozen (or mostly frozen) precipitation of very small, white, opaque grains of ice, usually less than 1 mm in diameter. They resemble snow pellets in external appearance, but are generally smaller, more flattened, and elongated. They neither shatter nor bounce when they hit a hard surface.
Snow Intensity	Intensity of snow, which is characterized as (1) "light" when the visibility is 1 km (5/8 statute mile) or more; (2) "moderate" when the visibility is less than 1 km (5/8 statute mile) but not more than 1/2 km (5/16 statute mile); and (3) "heavy" when the visibility is less than 1/2 km (5/16 statute mile). Snow intensity may be observed and reported at the surface and aloft.
Snow Pellets	Form of frozen (or mostly frozen) precipitation, usually of brief duration, consisting of crisp, white, opaque ice particles, round or conical in shape, and about 2 to 5 mm in diameter. Same as graupel or small hail.
Snow Shower	Brief period of snowfall in which intensity can be variable and may change rapidly. Some accumulation is not uncommon, although it is limited by the relatively brief nature of the shower. A snow shower in which only light snow falls for a few minutes is typically called a snow flurry. Snow showers are characterized by the suddenness with which they start and stop, by the rapid changes of intensity, and usually by rapid changes in the appearance of the sky.
Snowfall Rate	Speed with which snowfall is accumulating, expressed quantitatively in units of distance per unit time (e.g., inches per hour). Snowfall rate can be reported in an observation via the plain language SNINCR remark (e.g., a snow depth increase of 2 inches in the past hour with a total depth on the ground of 10 inches would be coded "SNINCR 2/10").
Solar Energetic Particle (SEP)	Atoms associated with solar flares. SEPs are a type of cosmic ray. SEPs move away from the sun due to plasma heating, acceleration, and numerous other forces.
Solar Radiation Storm	Storm caused by elevated levels of solar radiation that occur when the number of energetic particles (protons) increases.
Solar Wind	Outward flux of solar particles and magnetic fields from the sun. Typically, solar wind velocities are near 350 km/s.
Solid Precipitation	Any of various forms or types of frozen or partially frozen precipitation, including snow, sleet (ice pellets), hail, and variants or blends of these (including soft hail, graupel, snow pellets). May fall from cumuliform clouds (in potentially showery form) or from stratiform clouds (tending to be of low but consistent intensity). This can be observed and reported at the surface or aloft.
Space Weather	Activity on the sun's surface (e.g., solar flares) that can emit radiation as plasma (particles) or electromagnetic radiation (light). From NAS, "space weather" describes the conditions in space that affect Earth and its technological systems. Our space weather is a consequence of the behavior of the sun, the nature of Earth's magnetic field and atmosphere, and the Earth's location in the solar system."
Space Weather Parameters	Quantities and properties that can be measured, observed, or derived (calculated) that characterize the space environment. Examples include particle (e.g., proton or electron), X-ray, or other energy fluxes, solar flare indicators, particle belt indices, and solar extreme ultraviolet radiation (EUV) index.
Space Weather: Duration of Solar Radiation	Duration of solar radiation for a period of time (e.g., during the day when intensity exceeds a threshold Watts/meter2 (W/m2), or for the time extent of a geomagnetic storm).
Space Weather: Intensity of Solar Radiation	Radiant energy per unit time coming from a specific direction and passing through a unit area perpendicular to that direction. Also called radiance.
Space Weather: Onset of Solar Radiation	Moment when direct sunlight begins impinging upon a surface or object.
Space Weather: Where Solar Activity Significantly Degrades ATC Communications	Further investigation and research are needed to derive an authoritative definition for this concept. See entry entitled "Regions Where Solar Activity Significantly Degrades ATC Communications."
Space Weather: Where Solar Activity Significantly Degrades Navigation	Further investigation and research are needed to derive an authoritative definition for this concept. See entry entitled "Regions Where Solar Activity Significantly Degrades Navigation."

Term	Definition
Space Weather: Where Solar Radiation Poses a Biological Hazard (> 100 MeV) to Airliner Crews/Passengers	Further investigation and research may be needed to derive a final authoritative definition for this concept. See entry entitled "Regions Where Solar Radiation Poses a Biological Hazard (> 100MeV) to Airliner Crews/Passengers."
Speed of Thunderstorm Movement	Speed (in units of distance per time, such as m/sec) at which a thunderstorm is observed or estimated to be moving. Estimates can be radar based.
Squall	Strong wind characterized by sudden onset, duration on the order of minutes, and then sudden decrease in speed. At the start, the wind speed increases at least 16 knots and during the squall is generally sustained at 22 knots or more for at least 1–2 minutes (distinguishing it from a gust). Can include one or more precipitation types (e.g., snow squall or rain squall) and/or thunder ("thunder squall").
Station Altimeter	Pressure value to which an aircraft altimeter scale is set so that it will indicate the altitude above mean sea level of an aircraft on the ground at the location for which the value was determined (i.e., at the station). Reported in units of pressure (e.g., inches of mercury) and can be encoded in observations such as METARs.
Station Density Altitude	Altitude in the standard atmosphere at which the air has the same density as the air at the point in question. The pressure altitude corrected for temperature departures from the standard atmosphere. Useful for assessing the performance characteristics of aircraft (e.g., landing capability at high-altitude airports during very warm weather).
Station Pressure	Atmospheric pressure computed for the level of the station elevation (i.e., distance above sea level).
Statistical Reliability	Consistency of a set of measurements or forecasts. The extent to which the forecasts remain consistent over repeated simulations with permutated initial conditions or with variable (plausible) model physics. Reliability does not necessarily imply validity. That is, a reliable measure is measuring something consistently, but not necessarily what it is supposed to be measuring. The expected reliability of weather forecasts shows drastic variations depending on the daily flow configuration. On certain days, a 10-day forecast might have highly predictable features in it; on other days, a 3-day forecast might have features that have very little or no predictability. Ensemble forecasts can identify at the time a forecast is prepared how much predictability a particular weather feature has, given the initial uncertainty in the analysis and the time evolution of the possible atmospheric states up to a particular lead time of interest.
Stratification (Cloud Types Versus Layers)	See entry entitled "Sky Cover Stratification."
Stratiform Precipitation	Precipitation that has relatively extensive horizontal development, as opposed to the more vertical development characteristic of convection. Stratiform clouds tend to cover large areas, but show relatively little vertical development. Stratiform precipitation, in general, is relatively continuous and uniform in intensity (i.e., steady rain versus rain showers).
Sudden Ionospheric Disturbance (SID)	High-frequency (HF) propagation anomalies attributed to ionospheric changes resulting from solar flares, proton events, and geomagnetic storms.
Sufficiency	Quantity (enough) or quality of data for processing leading to product generation.
Sunspot	Relatively dark area on the surface of the sun consisting of a dark central umbra surrounded by a penumbra, which is intermediate in brightness between the umbra and the surrounding photosphere. Sunspots are often nearly circular with a typical diameter of 20,000 km. The strongest solar magnetic fields, up to 4,000 gauss, are found within the umbra. Sunspots usually occur in pairs with opposite magnetic polarities. They have a lifetime ranging from a few days to several months. Their occurrence exhibits roughly an 11-year period (the sunspot cycle).
Supercooled Liquid Droplets	Small spherical or near-spherical liquid water particles or drops that are suspended in the atmosphere at less than 32°F (0°C). Supercooled liquid droplets (SLD) pose a danger to aircraft because they can cause aircraft icing. They also pose a danger, secondarily, because they cause reduced visibility. SLDs are often involved in the formation of raindrops and hail.

Term	Definition
Surface	Horizontal plane whose elevation above sea level equals the field elevation. At stations where the field elevation has not been established, the surface refers to the ground elevation at the observation site.
Surface Icing Accretion Amount (1, 3, and 6 hours)	Thickness of ice buildup on solid objects that are exposed to freezing precipitation or to supercooled fog or cloud droplets. At the Earth's surface, this usually refers to glaze formation. The amount of ice can be roughly measured by an ice-accretion indicator. For airborne objects, ice accretion refers to any type of aircraft icing. The thickness can be measured over time (e.g., 1, 3, or 6 hours).
Surface Icing Accretion Rate	Rate (distance or thickness per unit time) of ice buildup on an unheated body. "Icing rate meters" measure this with, for example, rotating cylinders or discs, stationary airfoils, vibrating rods, and electrical- impedance devices. Icing conditions may be observed and reported categorically, such as trace, light, moderate, or severe.
Surface Icing Accumulation	Thickness of ice buildup on solid objects that are exposed to freezing precipitation or to supercooled fog or cloud droplets. At the Earth's surface, this usually refers to glaze formation, and the amount of ice can be roughly measured by an ice-accretion indicator instrument.
Surface Icing Conditions	Tendency for surface objects to accumulate ice, rime, and/or hoarfrost (e.g., from supercooled water droplets, frozen fog, freezing rain, or freezing drizzle).
Surface Maximum Temperature	Highest temperature during a continuous time interval (e.g., 24 hours midnight-to-midnight local time, or 3 hourly). A "maximum temperature" can be observed or forecast at the surface or aloft.
Surface Minimum Temperature	Lowest temperature during the a continuous time interval (e.g., 24 hours midnight-to-midnight local time, or 3 hourly). A "minimum temperature" can be observed or forecast at the surface or aloft.
Surface OTV (vertical extent)	Depth, or distance, as measured in the local vertical of an obstruction to vision. Different obstruction types have different criteria. "Drifting snow," for example, refers to wind-lifted snow whose height is less than 2 m, whereas "blowing snow" refers to wind-lifted snow raised to a height of 2 m or more.
Surface Pressure	Atmospheric pressure at the designated station elevation (see entry entitled "Station Pressure"). Sometimes refers to mean sea level pressure (see entry entitled "Sea Level Pressure").
Surface Pressure Change	Net difference between pressure readings at the beginning and ending of a specified interval of time.
Surface Pressure Tendency	Character and amount of atmospheric pressure change during a specified period of time, usually the 3-hour period preceding an observation, at the surface of the Earth.
Surface Temperature	Measure of the internal or kinetic energy, or heat, that a substance contains. It is generally measured by a thermometer and can be valid at the surface ("surface temperature") or aloft.
Surface Variable Wind	Condition when (1) the wind direction fluctuates by 60° or more during the 2-minute evaluation period and the wind speed is greater than 6 knots; or (2) the direction is variable and the wind speed is less than 6 knots.
Surface Weather	Category of individual and combined atmospheric phenomena that must be drawn on to describe the local atmospheric conditions at a specific time at the ground level or water level.
Surface Wind	Wind measured at a surface observing station.
Surface Wind Gust	Rapid fluctuation in wind speed, with a variation of 10 knots or more between peaks and lulls. The speed of the gust will be the maximum instantaneous wind speed.
Surface Wind Gust Direction	Direction of the maximum instantaneous wind speed.
Surface Wind Gust Speed	Maximum instantaneous wind speed.
Threshold	Value that, when passed, from below or above, initiates or limits an action For example, if a temperature goes above a preset threshold level, it might trigger an automated surface observing system [ASOS] to make a special observation; or if the RVR goes below a preset threshold level, a pilot may not be able to land at a specific airport.
Thunderstorm	Local storm invariably produced by a cumulonimbus cloud and always accompanied by lightning and thunder, usually with strong gusts of wind, heavy rain, and sometimes hail.

Term	Definition
Thunderstorm Cell Intensity	Intensity of a thunderstorm, reported as light, medium, or heavy according to the (1) nature of the lightning and thunder; (2) type and intensity of the precipitation, if any; (3) speed and gustiness of the wind; (4) appearance of the clouds; and (5) effect on surface temperature. From the synoptic meteorologist's viewpoint, thunderstorms may be classified by the nature of the overall weather situation (e.g., air mass thunderstorm, frontal thunderstorm, and squall-line thunderstorm).
Thunderstorm Cell Location	Description of a thunderstorm's spatial location. This position can be the direction (relative to a station) in a surface report (e.g., "TS SE MOV NE" corresponds to a thunderstorm to the southeast of a station, moving toward the northeast). Thunderstorm position also can be expressed as a latitude/ longitude pair. In addition, thunderstorm height (top) can be reported by radar or aircraft.
Thunderstorm Decay	Gradual deterioration of a thunderstorm's size or strength.
Thunderstorm Growth	Increase in size or strength of a thunderstorm.
Time	Value in the nonspatial dimension associated with an event. The nonspatial dimension describes a continuum in which events occur in apparently irreversible succession from the past through the present to the future. Time is used to synchronize activities throughout the NextGen.
Time Referenced	Associated with a particular moment in time or a time period. For example, temperature analysis grid valid at 1200 UTC on a particular day; radar image time valid over a 1-minute period between 1200 and 1201 UTC; model forecast temperature grid valid at 48 hours in the future (relative to a reference time).
Tornado	Violent, rotating, columnar whirlwind (vortex) of air touching the ground; a funnel cloud that touches the ground (see entries entitled "Funnel Cloud" and "Waterspout"). Usually appears as a pendant or extension from a cumulonimbus cloud. Tornadoes typically have diameters of roughly 10s to 100s of meters, and lifetimes typically within the range of 5 to 100 minutes. Tornadoes can be stationary or can move with their host clouds, sometimes covering 10s or (infrequently) 100s of kilometers. Tornadoes usually rotate cyclonically (although on rare occasions, anticyclonically) with wind speeds ranging from about 18 m s^{-1} (40 mph) to about 135 m s−1 (300 mph).
Tornado Beginning Time	Moment in time when a developing funnel cloud (or a debris cloud directly associated with a funnel cloud's base) makes contact with the ground. This time can be encoded in a surface report; for example, in a SPECI, as TORNADO B13 6 NE. This term signifies a tornado beginning time of 13 minutes past the previous hour.
Tornado Cloud Base Height	Height of the base (bottom) of the convective cloud that hosts a tornado. The base of a cloud (or cloud layer) is the lowest level in the atmosphere at which the air contains a perceptible quantity of cloud particles.
Tornado Direction of Movement	Direction toward which precipitation is moving. This direction can be radar estimated, or can be human observed and encoded in a surface report; for example, in a SPECI, as TORNADO B13 6 NE. This term signifies a tornado (beginning time of 13 minutes past the previous hour) moving in a northeasterly direction.
Tornado Ending Time	Moment in time when a developing funnel cloud (or a debris cloud directly associated with a funnel cloud's base) loses contact with the ground or dissipates outright. This time can be encoded in a surface report; for example, in a SPECI, as TORNADO E13. This term signifies a tornado ending time of 13 minutes past the previous hour.
Tornado Intensity	Measure of the severity of a tornado. This can be assessed by the strength of the vortex winds within a tornado (as measured by anemometer or radar). Tornado intensity is assessed retrospectively in the United States using the Enhanced Fujita (EF) scale, which uses a standard set of storm damage indicators to estimate storm intensity. Tornadoes are assigned an EF number ranging from EF-0 (relatively weak tornado) to EF-5 (very strong tornado).
Tornado Movement Speed	Speed (in units of distance per time, such as m/sec) at which a tornado is observed or estimated to be moving. Estimates can be radar based.
Total Electron Content (TEC)	Descriptive quantity for the ionosphere of the Earth; total number of electrons present along a path between two points, with units of electrons per square meter, where 1,016 electrons/m^2 = 1 TEC unit (TECU). TEC is significant in determining scintillation and group delay of a radio wave through a medium. Ionospheric TEC is characterized by observing carrier phase delays of received radio signals transmitted from satellites located above the ionosphere, often using GPS satellites. TEC is strongly affected by solar activity.

Term	Definition
Tower Visibility	Prevailing visibility observed from an airport or air traffic control tower. This tower visibility can be in addition to (i.e., a separate observation of) the airport surface visibility observed or measured at a different (non-tower) location on the airport. According to current U.S. weather observing practice, at civil stations the control-tower visibility becomes the official visibility for the station whenever the surface visibility becomes less than 3 miles.
Traffic Capacity	Maximum number of aircraft that can be accommodated in a given time period by the system or one of its components (throughput).
Turbulence	Irregular motion of the atmosphere, as characterized by rapid changes in velocity in time and space. This motion causes irregular motions of aircraft flying in the vicinity, which may experience rapid up-and-down or side-to-side motions and changes in airspeeds caused by a rapid variation in atmospheric wind velocities. This action may occur in cloudy areas (particularly, towering cumulus and lenticular clouds) or in clear air. Turbulence is the leading cause of nonfatal passenger and flight attendant injuries. The FAA classifies aircraft turbulence as Light, Moderate, Severe, or Extreme. Causal agents include air flow over topography (mountain waves), thermal instability, dynamic instability, and wind shear.
Unknown Precip	Precipitation type that is reported if an automated station detects the occurrence of precipitation, but the precipitation discriminator cannot recognize the precise type (i.e., it cannot be established whether the precipitation type is rain, ice pellets, freezing rain, hail, or some combination thereof).
User	Service provider or end user that needs weather product(s) or information to perform an aviation-related function.
User Access	User's ability to communicate with, especially by computer, products, information, and other users.
Variable Cloud Ceiling	Cloud ceiling that increases or decreases rapidly by specified amounts. When the height of a cloud ceiling layer increases and decreases rapidly by the amounts given in the Federal Meteorological Handbook, Number 1 (FMH-1), Table 9-2, during the evaluation period, it shall be considered variable and the ascribed height shall be the average of all the varying values.
Variable Prevailing Visibility	Description of visibility when the prevailing visibility rapidly increases and decreases by ½ statute mile or more during the time of the observation and the prevailing visibility is less than 3 miles.
Variable Surface Winds	Description of surface winds when during the 2-minute evaluation period the wind speed is 6 knots or less. Also, the wind direction shall be considered variable when, during the 2-minute evaluation period, it varies by 60 degrees or more when the average wind speed is greater than 6 knots.
Vertical Extent of In-Flight Icing	Depth(s) of atmosphere where icing is observed or forecast. This can consist of one or more layers, each defined by a base elevation and a top elevation.
Vertical Extent of Low Level Wind Shear	Depth(s) of atmosphere where low-level wind shear is observed or forecast. This can consist of one or more layers, each defined by a base elevation and a top elevation.
Vertical Extent of Thunderstorm	Vertical area of a thunderstorm.
Vertical Extent/ Altitude of Volcanic Ash	Vertical area tied to the vertical position of a volcanic ash plume.
Virga	Visible wisps, streaks, or strands of precipitation falling from clouds and that are evaporating before they reach the surface. In certain cases, shafts of virga may precede a microburst. See entry entitled "Microburst."
Visibility	Greatest distance in a given direction at which it is barely possible to see and identify with the unaided eye (1) in the daytime, a prominent dark object against the sky at the horizon, and (2) at night, a known, preferably unfocused, moderately intense light source. After visibilities have been determined around the entire horizon circle, they are resolved into a single value of prevailing visibility for reporting purposes. Visibility may be observed or reported at the surface or aloft.
Visibility (FAA)	Ability, as determined by atmospheric conditions and expressed in units of distance, to see and identify prominent unlighted objects by day and prominent lighted objects by night. Visibility is reported in units of statute miles, feet, or meters.
Visibility, Flight (FAA)	Average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent unlighted objects may be seen and identified by day and prominent lighted objects may be seen and identified by night.

Term	Definition
Visibility, Ground (FAA)	Prevailing horizontal visibility near the Earth's surface, as reported by the U.S. NWS or an accredited observer.
Visibility, Prevailing (FAA)	Greatest horizontal visibility equaled or exceeded throughout at least half of the horizon circle, which need not necessarily be continuous.
Visibility: Mid-RVR (FAA)	RVR readout values obtained from RVR equipment located midfield of the runway.
Visibility: Rollout RVR (FAA)	RVR readout values obtained from RVR equipment located nearest the rollout end of the runway.
Visibility: Runway Visibility Value (RVV) (FAA)	Visibility determined for a particular runway by a transmissometer, which provides a continuous indication of the visibility (reported in miles or fractions of miles) for the runway. RVV is used in lieu of prevailing visibility in determining minimums for a particular runway.
Visibility: Runway Visual Range (RVR) (FAA)	Instrument-derived value, based on standard calibrations, that represents the horizontal distance a pilot can see down the runway from the approach end. It is based on the sighting of either high-intensity runway lights or on the visual contrast of other targets, whichever yields the greater visual range. RVR, in contrast to prevailing or runway visibility, is based on what a pilot in a moving aircraft should see when looking down the runway. RVR is horizontal visual range, not slant visual range. It is based on the measurement of a transmissometer made near the touchdown point of the instrument runway and is reported in hundreds of feet. RVR is used in lieu of RVV and/or prevailing visibility when determining minimums for a particular runway.
Visibility: Touchdown RVR (FAA)	RVR visibility readout values obtained from RVR equipment serving the runway touchdown zone.
Volcanic Ash	Fine particles of rock powder that originate from a volcano and that may remain suspended in the atmosphere for long periods. Volcanic ash should always be reported as a "present weather" type when observed.
Volcanic Ash Cloud 3-D Extent of	Three spatial dimensions of a volcanic ash cloud. This can be expressed in terms of minimum and maximum altitude, horizontal boundaries (e.g., latitude/longitude coordinates), a point and radius, or on 3-D grids.
Volcanic Ash Cloud Movement	Fine particles of mineral matter from a volcanic eruption can be transported long distances by winds aloft. Such transport can be observed or forecast. Observations and forecasts of volcanic ash cloud motion can be represented as a wind vector, or as future representations of the 3-D cloud extent. Manual reporting stations should report observed ash cloud movements in the plain language remarks of an observation (e.g., MT. AUGUSTINE VOLCANO 70 MILES SW ERUPTED 231505 LARGE ASH CLOUD EXTENDING TO APRX 30000 FEET MOVING NE).
Volcanic Ash Dispersion	Transport, diffusion, and dilution of volcanic ash. Manual reporting stations should report observed ash cloud dispersion in the plain language remarks of an observation (e.g., MT. AUGUSTINE VOLCANO 70 MILES SW ERUPTED 231505 LARGE ASH CLOUD EXTENDING TO APRX 30000 FEET MOVING NE).
Wake Vortex (WV)	Region of turbulence to the rear of an in-flight aircraft. Under certain conditions, a series of vortices may form in the wake of an aircraft, and persist or extend downstream in a manner and configuration that depends on many factors (e.g., aircraft type, local atmospheric stability, and local wind fields). A "wake vortex" train sometimes develops in a turbulent wake, and this train is sometimes referred to as a "vortex street." Wake vortices and related phenomena may pose serious problems for encountering aircraft.
Wake Vortex Displacement	Displacement distance of the departure or arrival trajectories of successive aircraft, which is intended to minimize the likelihood of wake vortex interference of following aircraft. The displacement distance of the wake vortex from the actual trajectory of the generating aircraft.
Wake Vortex Dissipation	Decay of wake vortices, which can be represented as time, distance (behind/beneath source aircraft), or wind velocity deceleration (e.g., m/sec^2).
Warning	Issued when a hazardous weather or hydrologic event is occurring, is imminent, or has a very high probability of occurring. A warning is used for conditions posing a threat to life or property.
Watch	Issued when the risk of a hazardous weather or hydrologic event has increased significantly, but its occurrence, location, and/or timing are still uncertain. It is intended to provide enough lead time so that those who need to set their plans in motion can do so.

Term	Definition
Waterspout	In general, any tornado over a body of water. Usually weaker than (somewhat similar, land-based) tornadoes, a waterspout is a rapidly rotating column of air over water beneath a cumulonimbus or towering cumulus cloud. Waterspouts remain in contact with the body of water beneath. Waterspouts are most common over tropical or subtropical waters.
Weather	Category of individual and combined atmospheric phenomena that must be drawn on to describe the local atmospheric conditions at a specific time.
Weather Data	See entry entitled “Data (Weather).”
Weather Element	Any one of the observable properties of the atmosphere (i.e., temperature, humidity, precipitation), which together specify the physical state of weather or climate at a given place for any particular moment or period of time
Weather Information (classified)	Data withheld (i.e., of strictly limited availability and distribution) for national security reasons.
Weather Information (unclassified)	4-D Wx Data Cube data (used directly and indirectly for aviation decisions) that is not classified. Note that this includes freely available public domain weather information, as well as data restricted for reasons other than a classified rating (e.g., regulatory or proprietary information).
Weather Information (proprietary)	Information over which private ownership and control are exercised. This information may still be in the 4-D Wx Data Cube, but in general, access to it and/or its dissemination is controlled.
Weather Information (public domain)	Weather information in the 4-D Wx Data Cube whose access is unrestricted. This includes information whose visibility and use is not limited because it is unclassified, proprietary, or restricted regulatory.
Weather Model	Software program or application that uses algorithms generally used for numerical weather diagnosis and prediction (e.g., RUC, AVN, ETA).
Well-Developed Dust/Sand Whirls	Ensemble of particles of dust or sand, sometimes accompanied by small litter, raised from the ground in the form of a column of varying height with a small diameter and an approximately vertical axis. A dust whirl is a rotating column of air rendered visible by dust or sand.
White Light	Sunlight integrated over the visible portion of the spectrum (4,000 to 7,000 angstroms) so that all colors are blended to appear white to the eye.
Widespread Dust	Fine particles of the Earth or other matter raised or suspended in the air by wind that may have occurred at or far away from the station and that may restrict horizontal visibility.
Wind	Horizontal motion of the air past a given point.
Wind Direction	True direction from which wind is blowing at a given location (i.e., wind blowing from the north to the south is a north wind). It is normally measured in 10s of degrees from 10 degrees clockwise through 360 degrees. North is 360 degrees. A wind direction of 0 degrees is used only when wind is calm. Winds may be measured and reported near the surface (typically at 10 m elevation) or aloft. Winds are sometimes reported categorically by direction (e.g., NE, ENE, E).
Wind Gust	Relatively sudden, brief, increases in wind speed, where the peak wind speed reaches at least 16 knots, and the variation between the peak wind and the lulls is more than 9 knots. The duration of a gust is generally less than 20 sec. The speed of the wind gust is the maximum near-instantaneous speed. For observing purposes, the wind speed data for the most recent 10 minutes shall be examined to evaluate the occurrence of gusts. Wind gusts should be reported in surface observations (METARs or SPECIs) as, for example, 27020G35KT, which refers to a reported wind gust of 35 knots. Wind gust speed and direction are reported consistently with wind speed and wind direction, respectively.
Wind Profile	Graph or plot of the wind versus a horizontal, vertical, or time scale. The change in wind speed and/or direction usually in the vertical and based on a number of wind observations or forecasts at various levels. The characteristics of the wind shear profile are of critical importance in determining the potential for and type of severe weather. A wind profile may be based on in situ measurements (e.g., radiosonde) or remote measurements (e.g., via satellite, profiler, or radar). Doppler radar plots of horizontal winds (as a function of height above a radar) are sometimes plotted with height as the vertical axis and time as the horizontal axis (a so-called time-height display), which then depicts the change in wind with time at various heights. Model-based wind profiles are frequently used for analyzing and prognoses of wind shear.

Term	Definition
Wind Shear	Rate at which wind velocity changes from point to point in a given direction (e.g., vertically). The shear can be speed shear (where the speed changes between the two points but not the direction), direction shear (where the direction changes between the two points but not the speed), or a combination of the two.
Wind Shift	Change in the wind direction of 45 degrees or more in less than 15 minutes with sustained wind speeds of 10 knots or more throughout the wind shift.
Wind Speed	Rate at which air is moving horizontally past a given point. It may be a 2-minute average speed (reported as wind speed) or an instantaneous speed (reported as a peak wind speed or gust). It can be observed or reported near the surface (typically 10 m elevation) or aloft.
Winds at Runway Departure	Evaluation of the wind speed and direction observed at the end of the portion of the runway usable for landing.
Winds at Runway Mid-Point	Evaluation of the wind speed and direction observed at the mid-point of the portion of the runway usable for landing.
Winds at Runway Threshold	Evaluation of the wind speed and direction observed at the beginning of the portion of the runway usable for landing.
World Area Forecast System (WAFS)	Program developed by the International Civil Aviation Organization (ICAO) and the World Meteorological Organization (WMO) to improve the quality and consistency of en route guidance provided for international aircraft operations. Currently, two World Area Forecast Centers (WAFC), one in the United States and one in the United Kingdom, are providing en route wind and temperature forecasts and some significant weather charts. In the final phase of the WAFS, en route significant weather forecasting responsibilities also will be fully transferred to the two WAFCs. WAFC-Washington is responsible for satellite data broadcasts to the Americas, the Atlantic, the Pacific, and Eastern Asia Backup. WAFC-London is responsible for broadcasts to Europe, Africa, and western Asia.

APPENDIX G. ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition
4-D Wx Data Cube	Four-Dimensional Weather Data Cube
4-D Wx SAS	Four-Dimensional Weather Single Authoritative Source
ADDS	Aviation Digital Display System
ADF	Airline Dispatchers Federation
AK	Alaska
AMS	American Meteorological Society
ANSP	Air Navigation Service Provider
AOC	Air and Space Operations Center
AOPA	Aircraft Owners and Pilots Association
APA	Allied Pilots Association
ASOS	Automated Surface Observing System
ATA	Air Transport Association
ATA	Arrival Transition Area
ATC	Air Traffic Control
ATM	Air Traffic Management
ATO	Air Traffic Organization (FAA)
ATO-R	Air Traffic Organization–System Operations Services
BUFR	Binary Universal Form for the Representation of Meteorological Data
C&V	Ceiling and Visibility
CAT	Clear Air Turbulence
CIG	Ceiling
CIP/FIP	Current/Forecast Icing Potential
CIT	Convective Induced Turbulence
ConOps	Concept of Operations
CONUS	Continental United States
COP	Common Operating Picture
CPU	Central Processing Unit
CTAS	Center-TRACON Automation System
DOD	Department of Defense
DST	Decision Support Tool
DTA	Departure Transition Time
EA	Enterprise Architecture
EDR	Eddy Dissipation Rate
EMC	Environmental Modeling Center (NCEP)
ERAU	Embry Riddle Aeronautical University
FAA	Federal Aviation Administration
FCM	Flow Contingency Management
FIDO	Forecast, Integration, Dissemination, Observation
FIR	United States Flight Information Region
FL	Flight Level
FPAW	Friends and Partners in Aviation Weather
GA	General Aviation
GFS	Global Forecast System
GIG	Global Information Grid
GRIB2	General Regularly Distributed Information in Binary
HDF5	Hierarchical Data Format
HF Comms	High-Frequency Communications
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IMC	In Meteorological Conditions
IOC	Initial Operating Capability
IWP	Integrated Work Plan
JSAT	Joint Safety Analysis Team
JSIT	Joint Safety Implementation Team
JPDO	Joint Planning and Development Office
METAR	Aviation Routine Weather Report

Acronym/Abbreviation	Definition
METAR/SPECI	Aviation Routine Weather Report/Aviation Selected Special Weather Report
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
NAM	North American Mesoscale
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NBAA	National Business Aviation Association
NCEP	National Center For Environmental Prediction
NCO	NCEP Central Operations
NCO O&M	NCO Operations and Maintenance
NEO	Net Enabled Operations
NEXRAD	Next Generation Radar
NextGen	Next Generation Air Transportation System
NOAA	National Oceanic and Atmospheric Administration
NWA	Northwest Airlines
NWS	National Weather Service
OEP	Operational Evolution Partnership
OI	Operational Improvement
PIREPS	Pilot Reports
PNT	Position, Navigation, Timing Services
R&D	Research and Development
RAA	Regional Airline Association
ROM	Rough Order of Magnitude
RUC	Rapid Update Cycle
RVR	Runway Visual Range
SAMA	Small Aircraft Manufacturers Association
SAS	Single Authoritative Source
SEM	Systems Engineering Manual (FAA)
SIGMETS	Significant Meteorological Information
SLD	Super-Cooled Liquid Droplet
SME	Subject Matter Expert
SPC	JPDO Senior Policy Committee
SREF	Short-Range Ensemble Forecast
SSA	Shared Situational Awareness
SWA	Southwest Airlines
SWIM	System-Wide Information Management
TAF	Terminal Area Forecast
TBD	To Be Determined
TBO	Trajectory-Based Operations
TFM	Traffic Flow Management
TFMM	Traffic Flow Management Modernization
TMU	Traffic Management Unit
TOR	Terms of Reference
TRACON	Terminal Radar Approach Control
UAL	United Airlines
UAS	Unmanned Aircraft System
URET	User Request Evaluation Tool
VFR	Visual Flight Rules
WAFC	World Area Forecast Center
WMO	World Meteorological Organization
WP	With Probability
WV	Wake Vortex
Wx	Weather
XML	Extensible Markup Language

APPENDIX H. VALIDATION SURVEY QUESTIONS AND DOCUMENTED USER NEEDS

Survey Questions for Validation of Weather Informational Needs

Weather has a major impact on today's air transportation and is expected to remain a significant factor in the Next Generation Air Transportation System (NextGen). In fact, the scope of weather in NextGen has been broadened beyond conventional atmospheric dynamics such as turbulence, winds, and precipitation to also include particulate plumes and space weather (e.g., radiation). Please take a moment to provide us with feedback regarding on thoughts about the future treatment of weather so that we can ensure that all relevant weather information is available and can be appropriately integrated into your future operational decisions.

Please provide your comments in the space provided.

1. Have you read the NextGen ConOps, specifically Chapter 5 about weather (Version 2.0, June 2007)? Have you read the Weather ConOps (Version 1.0, May 2006)?

2. If you responded YES to either or both, please give us your opinion from your operational point of view (e.g., with regard to weather, is anything missing or not well described/developed/understood?). If you answered NO, please go on to Question 3.

a. Anything missing?

b. Anything not well described/developed/understood (e.g., this sounds good on paper but will not work in the real world)? Explain.

NextGen is envisioned to bring new capabilities to many operational users, some of whom will depend on the availability and integration of weather information.

3. Please list all future capabilities which you expect to achieve through NextGen that can be affected by weather. For each capability listed, please rank from 1 (appropriate weather information will provide a modest amount of value in achieving/supporting the capability) to 5 (appropriate weather information will provide significant value in achieving/supporting the capability). Under each capability, please explain what and/or how appropriate weather information will improve or enable the capability. Please highlight any differences in weather information over that which is available today (e.g., need more resolution, need greater forecast skill, need specific weather data).

4. Aviation Mission Needs Statement #339 identifies the following operational decisions made by you today that are affected by weather:

<Specific operational decisions appropriate to the survey respondent are listed here>

As your business/operation evolves and as the NextGen vision is implemented, do you envision that these decisions will remain the same, or will some become more important compared with those today? Why? For example, new capabilities will change/modify required operational decisions. Explain.

Various User Weather Needs from Documented Sources

User Weather Need	Referenced Study	Users
Weather needs containing time and/or area constraints		
Wx information for ½ to 1 day ahead	Boeing study,1998	AOC, TFM
National-level convection forecasts for 8+ hours	Fahey, Phaneuf, Leber, Huberdeau, Morin, Sims, 2005	Dispatch, TFM
4- to 8-hour terminal area forecasts of convection, ceiling, visibility, surface winds, low-level wind shear and nonconvective turbulence, and present weather	Decision-Based Weather Needs, ARS Study, 1999	Center, TFM
4- to 8-hour gate area forecasts of convection and icing	Decision-Based Weather Needs, ARS Study, 1999	Center, TFM
Convection or convection forecast trend indications, especially 4 hrs+ out	Fahey, Phaneuf, Leber, Huberdeau, Morin, Sims, 2005	Dispatch, TFM
4- to 8-hour center area forecasts of convection, jet stream location and characteristics, CAT, and icing	Decision-Based Weather Needs, ARS Study, 1999	Center, TFM
3- to 6-hour forecasts of regional weather and winds	Boeing study, 1998	Dispatch, TFM
2- to 6-hour TRACON area forecasts	Fahey, Phaneuf, Leber, Huberdeau, Morin, Sims, 2005	Dispatch, TFM
1- to 4-hour terminal area forecasts of convection, ceiling, visibility, surface winds, low-level wind shear and turbulence, present weather	Decision-Based Weather Needs, ARS Study, 1999	Center, TFM
1- to 4-hour gate area forecasts of convection, icing, turbulence, ceiling, visibility	Decision-Based Weather Needs, ARS Study, 1999	Center, TFM
0- to 4-hour center area forecasts for convection, jet stream location and characteristics, CAT, icing, and ceiling	Decision-Based Weather Needs, ARS Study, 1999	Center, TFM
Impacts on arrival and departure structure, including departure procedures and standard terminal arrival routes and arrival transitions: Need to incorporate departure gates and arrival corner posts plus 40 to 60 nautical miles (nm) surrounding at least 1- to 2-hour forecasts	Fahey, Phaneuf, Leber, Huberdeau, Morin, Sims, 2005	Pilot, dispatch, TRACON TFM
Forecast terminal winds 30 min to 1 hr to be more proactive with the tower on airport and/or runway configuration	WET, 2007	TRACON
30-minute to 1-hour forecasts of icing, snow, and low IFR conditions in the terminal area	WET, 2007	TRACON
1 hour or less forecasts (down to 15 minutes)	WET, 2007	TRACON
0- to 1-hour terminal area forecasts of convection, ceiling, visibility, surface winds, low-level wind shear and turbulence, present weather	Decision-Based Weather Needs, ARS Study, 1999	Center, TFM
0-1 hour gate area forecasts of convection, icing, turbulence, ceiling, visibility	Decision-Based Weather Needs, ARS Study, 1999	Center, TFM
Current depictions up to 30-minute forecasts for various terminal weather hazards	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Current depiction up to 30-minute forecasts for location and intensity of precipitation reaching the ground.	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Current depiction up to 30-minute forecasts, in 10- and 20-minute timeframes of storm movement (speed and direction) based on the leading-edge contours of cells or cell groups	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Current depiction up to 30-minute forecasts of gust front and wind shift, including location and strength	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot

User Weather Need	Referenced Study	Users
Weather needs containing time and/or area constraints		
Current depiction up to 30-minute forecasts of wind shears as associated with gust fronts	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower
Current depiction up to 30-minute forecasts of microburst prediction (onset and ending), including indications of intensification or decay (runway specific)	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Current depiction up to 30-minute forecasts of microbursts containing airspeed losses greater than 60 knots (runway specific)	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Current depiction up to 30-minute forecasts of tornadoes	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Current depiction up to 30-minute forecasts of high-reflectivity storm location and movement	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Current depiction up to 30-minute forecasts of hail location and movement	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Current depiction up to 30-minute forecasts of high wake vortex prediction	Weather for Arrival and Departure Services, 2000	TRACON TMU, TRACON controllers, tower, pilot
Weather information for next 5 to 20 miles for separation and sequencing	Boeing study, 1998	Center, TRACON
5-minute weather information for safety	Boeing study, 1998	Tower
Increased observations in oceanic and data space regions	Boeing study, 1998	Center, TFM
Increased number of upper air observations	Boeing study, 1998	Pilots, Dispatch, TFM, center, TRACON
Observations and forecasts for mountainous areas	JSAT/JSIT, 2000	Pilots
Improved detection and prediction of moderate to severe turbulence	Boeing study, 1998	Pilots, dispatch, center, TRACON
Regional weather forecasts versus national forecasts	Boeing study, 1998	TFM
Improved icing forecasts	JSAT/JSIT, 2000	Pilots
4-D gridded winds and temperatures to support en route transition	Boeing study, 1998	TRACON, center
Extended terminal forecasts, within 200 nm of airport	Boeing study, 1998	Dispatch, controllers, TRACON TFM
Customizable forecast for specific sites and geographic airspace	WET, 2007	TRACON
Horizontal depictions in several vertical layers over the TRACON area	WET, 2007; Weather for Arrival and Departure Services, 2000	TRACON
Incorporation of high-resolution observational networks across the TRACON area	WET, 2007	TRACON
Increased low-altitude observations	JSIT/JSAT, 2000	Pilots
Recapture of increased capacity or throughput times and areas after weather clears	Fahey, Phaneuf, Leber, Huberdeau, Morin, Sims, 2005	Pilot, dispatch
Information lacks sufficient precision and granularity	Fahey, Phaneuf, Leber, Huberdeau, Morin, Sims, 2005	Pilots, dispatch
Increase accuracy and precision of products such as convection, reduced visibility, icing, turbulence	JSAT, JSIT, 2000	Pilots
Forecasts of IMC conditions aloft	JSAT, JSIT, 2000	Pilots
Highly accurate winds and ceiling in terminal area	WET, 2007	TRACON

User Weather Need	Referenced Study	Users
Weather needs containing time and/or area constraints		
Visibility forecasts when affected by pollution, especially in western areas	Boeing study, 1998	TRACON, tower
Improved ceiling and visibility forecasts	Boeing study, 1998	Tower, TRACON, center, TFM
Convection growth and decay trends, as well as speed and direction of movement within terminal area	WET, 2007	TRACON
Terminal area guidance forecasts at smaller airports (but with GPS approaches)	JSAT, JSIT, 2000	Pilots
Flight verification of forecast weather products	JSAT/JSIT, 2000	Pilots
Incorporation of local airspace and weather phenomena nuances	WET, 2007	TRACON
Forecast winds adjusted by observation networks around terminals	Boeing study, 1998	TRACON, tower
Vertical distributions of winds, temperatures, and turbulence for wake vortex dissipation	Boeing study, 1998	TRACON, tower
Collect atmospheric humidity data at altitudes below 10,000 feet	JSAT, JSIT, 2000	Pilots
Climatology of airport environment for wake vortex mitigation	Boeing study, 1998	TRACON, tower
Miscellaneous		
Weather metrics for system performance (e.g., predictability, flexibility, user access, efficiency, delay)	Boeing study, 1998	All?
Weather forecasts that are accompanied by measures of uncertainty and reliability	Boeing study, 1998	All?

Validation of User Weather Needs—Weather Survey Contacts

Users	Contact	Affiliation	Title	E-mail/Phone	Phone
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	*Sid Huston	FAA	DFW TRACON		
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APPENDIX I. WEATHER REQUIREMENTS FUNCTIONAL ANALYSIS TEAM MEMBERS

Steve Abelman

Steve Abelman works in the National Weather Service's (NWS) Office of Science and Technology as the aviation focal point. Mr. Abelman has worked in aviation meteorology for more than 20 years, including four years with Weathernews in Norman, Oklahoma, as manager of Aviation Training and Standards. Before Weathernews, he worked for almost 15 years as an operational aviation forecaster with American Airlines in Ft. Worth, TX. Mr. Abelman received a B.S. in Meteorology from Northern Illinois University and completed a three-year stint with the NWS office in Corpus Christi, TX, before leaving to join American Airlines.

Frances Bayne

Frances Bayne is a member of the Federal Aviation Administration (FAA) Air Traffic Organization (ATO) Operations Planning Service, Systems Engineering Support Services, Requirements Development Team at the William J. Hughes Technical Center. Ms. Bayne has more than 20 years of experience in test and evaluation (T&E) of multiple software applications of the NAS Infrastructure Management System (NIMS). A former member of the NIMS Product Team, she was a member of multiple working groups, including the NIMS Requirements Working Group, and participated in many acquisition activities, all of which included developing documentation. Her extensive T&E, requirements, and documentation development experience prepared her for her current Requirements Development Team tasks. Ms. Bayne holds a B.S. in Computer Information Systems from Richard Stockton College of New Jersey and a Master of Aviation Management (M.A.M.) from Embry-Riddle Aeronautical University.

William Brown

William Brown has 11 years of experience as an engineer on FAA En Route automation and weather programs. He began his career at the William J. Hughes Technical Center working on automation programs as a support contractor in engineering, test, and evaluation. He joined the FAA in 2002 as an Electronics Engineer with the Weather Processors Group. Mr. Brown holds a B.S. in Electrical Engineering (BSEE) from Drexel University. He joined En Route and Oceanic Program Operations in 2006, where he serves primarily in the Weather and Radar Processor Program Office.

Larry Burch

Larry Burch is Deputy Director of National Oceanic and Atmospheric Administration's (NOAA) NWS Aviation Weather Center. He has worked for 32 years as a federal government meteorologist, primarily in the area of aviation weather forecasting. Previous assignments included 12 years at Center Weather Service Units and five years as a senior forecaster in a Weather Forecast Office. He also is a former regional program manager for aviation services. Mr. Burch is an ATP-rated pilot with more than 2,500 flight hours.

Brian Gockel

Since 2004, Brian Gockel has been a meteorologist and engineer in the NWS Office of Science and Technology. Areas of current emphasis are network analyses, planning, data management, and transition of developmental products to NWS operations. For example, he recently coordinated the addition of high-resolution National Centers for Environmental Prediction

(NCEP) Rapid Update Cycle (RUC) model products to the NOAAPort and Advanced Weather Interactive Processing System (AWIPS) suite. He also provides support in long-term, broad-scale planning, including exploring interfaces between evolving NWS systems and other under-development systems such as NPP, NPOESS, and GOES-R satellites. Mr. Gockel worked for 20 years before joining NWS, chiefly as a government contractor in software development, systems engineering, task leadership, and business development for major weather systems such as NEXRAD (WSR-88D), TDWR, CLASS, POES, and GOES. He also has research experience in mesoscale and photochemical atmospheric modeling, and was a volunteer cooperative weather observer. He holds a B.S. in Computer and Information Science and a B.S. and M.S. in Meteorology.

Aaron Gray

Since 2006, Aaron Gray has been a Senior Program Analyst with NOAA NWS in the Office of the Chief Financial/Administrative Officer (CFO). He is responsible for developing budget, corporate performance, and other strategic and management tools to ensure proper NWS operations. His budget work includes developing narratives, costing, and performance parameters for budgetary submissions to the Department of Commerce and the Office of Management and Budget (OMB). Corporate performance includes developing and reporting on Government Performance and Results Act (GPRA) measures, assisting in Program Assessment and Rating Tool (PART) assessments, and developing annual operating plans (AOP). Before joining NWS, Mr. Gray was a Survey Statistician with the Bureau of the Census, Governments Division, from 2003 to 2006, and he has worked at the state and local levels in economic development and business planning in West Texas. He has received numerous awards, including the Director Award for Innovation in 2006, and various achievement awards and citations. He also completed the Leadership Development Program. Mr. Gray holds a B.A. in Political Science and Sociology and a Master's in Public Administration from Texas Tech University in Lubbock, TX. He is currently working toward a Juris Doctorate at the University of Baltimore School of Law in Baltimore, MD.

Michele Heiney

Dr. Michele Heiney has more than eight years of experience providing specialty engineering services in human factors and system safety engineering. She currently works in the Aviation Weather Office of the FAA. Her responsibilities include coordinating research and development (R&D) activities for the Next Generation Air Transportation System (NextGen) weather capabilities and serving as team lead for the NextGen Evaluation Capability Plan outlining the process for moving weather products from R&D into implementation. She has managed high-fidelity, human-in-the-loop Air Traffic Control (ATC) simulations. She earned a Ph.D. in Experimental Psychology and has a commercial pilot certificate (single-engine land and instrument rating). She has co-authored technical reports, has published articles in peer-reviewed scientific journals, and has had papers accepted at scientific conferences. Her education includes a Ph.D. and M.S. in Experimental Psychology from Virginia Commonwealth University, B.A. in Psychology, and A.A.S. in General Flight Technology from Purdue University.

Paul C. Jackson

Paul Jackson began his FAA career in 1983 as a Radar Associate Controller. He subsequently was certified as a Pilot Weather Briefer and continued as a Flight Service Automation Specialist. Building on his engineering degree, he earned an M.S. in Computer Science in 1995 from Johns

Hopkins University. Mr. Jackson left the FAA in 1996 to serve as a Software Engineer and Software Project Manager in private industry. He returned to the FAA in 2003 as a Computer Scientist with the Weather Processors team of the Weather and Flight Service Systems group, now part of En Route Program Operations. Mr. Jackson serves primarily in the Weather and Radar Processor (WARP) Program Office.

Nannette Gordner Kalani

Nannette Gordner Kalani has 25 years of experience working with aviation weather, and was a certified weather observer for the airlines and FAA. Her experience in the FAA includes pilot weather briefing in an automated flight service station; weather processor test and integration; weather system requirements and acquisition; and support of the Joint Program Development Office (JPDO) NextGen program in weather information dissemination. Currently, she is manager of the FAA's System Engineering Support Service's Architecture Planning Team supporting the National Airspace System Enterprise Architecture (NASEA) for several communication, dissemination, aeronautical information, and weather programs. Ms. Kalani holds a Bachelor of Business Administration (BBA) in Aviation Management from Wilmington College and an M.S. in Aviation Management from Embry Riddle Aeronautical University.

Guy Kemmerly

Guy Kemmerly is a Research Project Manager at NASA Langley Research Center. He received his B.S. in Aerospace and Ocean Engineering from Virginia Polytechnic Institute and State University in 1983 and has been working at NASA Langley since then. He conducted subsonic aerodynamic research for 15 years on military configurations and on the High-Speed Civil Transport, and he developed a new technique for estimating how airplanes fly when close to the ground. For seven years afterward, he supervised branches of researchers who developed research support tools. He was the Manager of NASA's Small Aircraft Transportation System (SATS) Project and of the Airportals Project, both aimed at moving people and products more efficiently. Most recently, he was Acting Deputy Director of NASA Langley's Aeronautics Research Directorate.

Bruce Lambert

Bruce Lambert is a Lieutenant Colonel in the US Air Force, where he has served 20 years as a weather officer supporting Air Force (AF) and Army aviation and ground operations. He has served in flight-line weather stations, reachback weather offices, and the AF climatology center. He has a B.S. in Aerospace Engineering from Boston University and an M.S. in Meteorology from Pennsylvania State University.

Jack May

Jack May is an independent consultant for endeavors in Aviation Meteorology. He served for six years as senior executive in charge of NOAA's Aviation Weather Center, located in Kansas City, MO. As Director of the Center, Mr. May was charged with motivating progress in improving services to the commercial aviation and the general aviation communities. He has collaborated with many national and international aviation organizations such as the Air Transport Association, Aircraft Owners and Pilots Association, and International Civil Aviation Organization. His NWS career spanned 32 years. He has a B.S. from Parks College of Aeronautical Technology and a Master's in Public Administration from Kansas University.

Cecilia Miner

Dr. Cecilia Miner has worked nearly 30 years in aviation meteorology. Currently, she is an aviation meteorologist at NWS headquarters in the Aviation Services Branch, where her primary focus is aviation weather for the NextGen. Before joining NWS, Dr. Miner supported FAA as an employee of AvMet Applications International. Before that, she served 22 years as an Air Force meteorologist in jobs that included operational forecasting, requirements and acquisition, and university teaching. Dr. Miner holds a B.S. in Mathematics from Mississippi State University, an M.S. in Systems Management from the University of Southern California, an M.S. in Atmospheric Sciences from Colorado State University, and a Ph.D. in Meteorology from Texas A&M University. She also is a private pilot and user of the aviation weather data.

Bill Mulokey

Bill Mulokey's areas of expertise include enterprise architecture, service-oriented architecture (SOA), systems engineering, requirements analysis, system design, system development and integration, configuration management, program management, leadership, complex problem-solving, technical innovation, and security engineering. Mr. Mulokey has more than 39 years of experience managing the development of information technology, communications, and automation systems for government and commercial clients. A Certified Enterprise Architect and Certified Information System Security Professional, he is technically accomplished as a systems and security engineer and knowledgeable in a wide range of hardware and software engineering technologies. He has successfully led multidisciplinary project teams through all system life-cycle phases. Mr. Mulokey, an associate at Booz Allen Hamilton, provides systems and security engineering and enterprise architecture expertise to government and commercial clients. As a certified and experienced DODAF architect, he has acquired an understanding of SOA and its applicability to the Global Information Grid (GIG) and NCES. Mr. Mulokey holds a B.S. in Electrical Engineering (BSEE) from Rensselaer Polytechnic Institute and an M.S. in Electrical Engineering (MSEE) from George Washington University.

Bob Showalter

As a Weather Systems Engineer with CSSI, Inc., Bob Showalter has for the past 12 years been supporting FAA weather systems engineering in developing the NAS/NextGen Weather Architecture, in addition to playing crucial roles in weather requirements, mission need/ investment analyses, and cost/benefits determinations. He has extensive knowledge of FAA, DOD, and NWS weather systems and architectures.

Cal Smith

Cal Smith has 32 years of experience in military and FAA air traffic control, and has worked in towers, approach controls, and flight service. He has practical experience in observation and pilot weather briefing. Mr. Smith also has been involved in developing automated weather systems and weather radar processors. He is currently a requirements specialist for the Air Traffic Organization–Terminal for all weather activities. He also is a private pilot with an instrument rating.

Walter Smith

Walter Smith is a retired U.S. Air Force Air Weather Service Chief, Weather Station Operations. Mr. Smith currently serves as data traffic manager for the NWS Telecommunications Operation Center. He was selected as a NWS 4-D Wx Cube team member based on his extensive

background in aviation weather and his experience in telecommunication/information systems management.

Cheryl Souders

Cheryl Souders has been Chief System Engineer for Weather at the FAA for 8 years. She is co-author of the FAA's *System Engineer Manual* and the instructor for the Functional Analysis course. Ms. Souders has more than 30 years of experience in systems engineering and aviation weather. She led the four-person team that developed the NextGen Weather Concept of Operations (CONOPS) and served as the functional requirements team lead. Ms. Souders holds a B.A. in Mathematics and Chemistry, a B.S. in Meteorology and an M.S. in Meteorology (from the Naval Postgraduate School).

R. Scott Stevens

Scott Stevens serves as a meteorologist in the FAA's Weather Policy and Requirements group, where he is responsible for coordinating the collection, validation, and prioritization of the aviation weather research and development requirements. Before joining the FAA, Mr. Stevens served in the U.S. Navy, where he held various positions as a leader, manager, and meteorologist. Primary assignments included the following: Meteorology and Oceanography Officer at the Naval Pacific Meteorology and Oceanography Command Center West/Joint Typhoon Warning Center, Guam; Meteorology and Oceanography Officer at the Fleet Numerical Meteorology and Oceanography Center, California; Officer in Charge of the Meteorology and Oceanography Detachment, Diego Garcia; and Technology Services Department Head at the Naval Pacific Meteorology and Oceanography Center/Joint Typhoon Warning Center, HI. Mr. Stevens holds an A.A. degree from the University of Hawaii, a B.S. in Physical Oceanography from the University of Washington, and an M.S. in Meteorology and Physical Oceanography from the Naval Postgraduate School.

James Tauss

James Tauss has 20 years of experience as a systems engineer, with primary focus on weather-related air traffic control systems, weather sensors and processors, and supporting architectures. Mr. Tauss has a comprehensive background with FAA and NOAA meteorological systems engineering management, T&E, specification compliance, systems acquisition, requirements/ functional analysis and definition, validation, policy, meteorological systems commercial definition and application, and meteorological training. He completed undergraduate studies in Physics and Earth Science at Adelphi University in New York. Mr. Tauss completed graduate studies in Meteorology at the University of Maryland at College Park.

ADDITIONAL SIGNIFICANT CONTRIBUTORS

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Dr. Geoff DiMego has been Chief of the Mesoscale Modeling Branch within the Environmental Modeling Center of NCEP since 1993, having spent the past 30 years at NCEP and its predecessor, the National Meteorological Center (NMC). He was a member of various NCEP and NMC branches (e.g., Systems Evaluation, Atmospheric Analysis, Short-Range Modeling and Regional and Mesoscale Modeling) and has been involved with most major operational regional analysis and modeling implementations (e.g., LFM, NGM, ROI, RDAS, ETA, EDAS, 3DVAR, RUC, WRF, and AQFS). Dr. DiMego holds a B.S. in Meteorology from The Pennsylvania State University and an M.S. and Ph.D. in Atmospheric Science from the State

University of New York at Albany. He received Department of Commerce Bronze (2), Silver, and Gold medals. In 2004, he received the NOAA Administrator's Award. He also is an AMS Fellow.

Joe Kunches

Joe Kunches is a space scientist at NOAA's NWS Space Weather Prediction Center in Boulder, CO, a national and international center for space weather services. He is Secretary of the International Space Environment Service (ISES), a consortium of 12 nations plus the European Space Agency, that is chartered to share space weather data and forecasts under the auspices of the International Council of Science (ICSU). He is a member of the editorial advisory board of the quarterly journal *GPS Solutions*, and also a member of the American Geophysical Union, Institute of Navigation, and International Loran Association. He continues to draw on his experience as a long-time operational space weather forecaster and will soon begin his fifth solar cycle in the space weather field. Mr. Kunches holds a B.S. in Aerospace Engineering from Notre Dame and an M.B.S. from the University of Colorado at Boulder.

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APPENDIX K. RECOMMENDATIONS FOR NEXT VERSIONS OF NEXTGEN CONCEPT OF OPERATIONS AND WEATHER CONCEPT OF OPERATIONS

A challenge for most writers is the task of conveying thoughts in ways that readers can easily understand. Conveying complex concepts like the use of weather in NextGen is particularly difficult. Future versions of the NextGen ConOps and the Weather ConOps, though intended for aviation stakeholders, should be written for those who are not familiar with all aspects of aviation and aviation weather. These concept documents are not intended as source documents for designers and engineers; those documents will be written in the future. NextGen ConOps documents are intended for aviation stakeholders who must gain an understanding of the concept. Therefore, the next version of ConOps should minimize the use of jargon and narrowly used industry terms. Congress is expected to sign the Plain Language Act this year, and ConOps writers should review the U.S. Government's Plain Language guidelines (*plainlanguage.gov*) to ensure that the rewrites of these documents meet the minimum Plain Language criteria.

Because the NextGen ConOps and the Weather ConOps were written a year apart, the terminology is not always consistent between the two documents. For example, the NextGen ConOps uses terms such as NextGen, NextGen Network Enabled Weather (NNEW), and Flow Contingency Management (FCM), whereas the Weather ConOps uses NGATS, Network Enabled Weather Information Sharing (NEWIS), and Traffic Flow Management (TFM). In addition, terminology is not always consistent within the same ConOps document. For example, in the NextGen ConOps, the term "Flow Contingency Management (FCM)" replaces today's term, "Traffic Flow Management (TFM)," and in the same document, "traffic flow management (TFM)" is used in Table 2-1 under the 2025 NextGen Capability column. Such discrepancies are not unexpected when multiple people are involved in writing one or more related documents. Ensuring consistency between the NextGen ConOps and the Weather ConOps should be a primary goal of the next writing effort.

The JPDO Weather Functional Requirements Study Team and the JPDO Weather Policy Study Team spent considerable time discussing the content and users of the NextGen ConOps *common weather picture*. For example, the NextGen ConOps states that the common weather picture is "for all air transportation decisionmakers and aviation system users," and that it is "used by all stakeholders." It further states that the common weather picture is "enabled by the single authoritative source capability."[1] The Weather Functional Requirements Study Team determined that the ConOps documents did not adequately distinguish between the portion of the common weather picture that is network-enabled, internally consistent, resilient, responsive, and has the needed high resolution for ATM decisionmaking (the 4-D Wx SAS) and the rest of the network-enabled weather information in the 4-D Wx Data Cube. Future versions of the NextGen ConOps and the Weather ConOps should use the definitions of 4-D Wx Data Cube and 4-D Wx SAS as defined in Section 1.1.1.

[1] NextGen Concept of Operations, Executive Summary, p. ES-3

The following comments received from the validation survey should be considered when completing the next version of the NextGen ConOps:

- The ConOps seems very aggressive given known difficulties of significant change in a tight budget environment.
- The ConOps should address the transition of functions performed today and those that will be performed at full NextGen implementation. For example, a description of equipage changes on the ground and in the flight deck would be helpful.
- The ConOps should provide more explanation of how the use of weather information will change ATM procedures during NextGen operations. Some respondents said they would like more explanation about airspace restrictions issued as a result of information provided by decision support tools.
- The ConOps should provide more thorough and complete explanations of operational concepts specific to general aviation.
- The ConOps should provide more details regarding the new training and educational needs that it introduced.

APPENDIX L. ROUGH ORDER OF MAGNITUDE (ROM) COST ESTIMATE FOR NEXTGEN "CREATE 4-D SAS WEATHER INFORMATION" FUNCTION

The Functional Requirements Study Team asked Dr. Geoff DiMego, Chief of the Mesoscale Modeling Branch and subject matter expert (SME) at the National Weather Service (NWS) Environmental Modeling Center, to provide a cost estimate for creating and operating a capability to produce seamless, consistent weather information for the 4-D Wx Single Authoritative Source (SAS). Appendix L presents details of this cost estimate to meet the functional and performance requirements of the 4-D Wx SAS.

Table L-1 lists requirements for the end state of the NextGen.

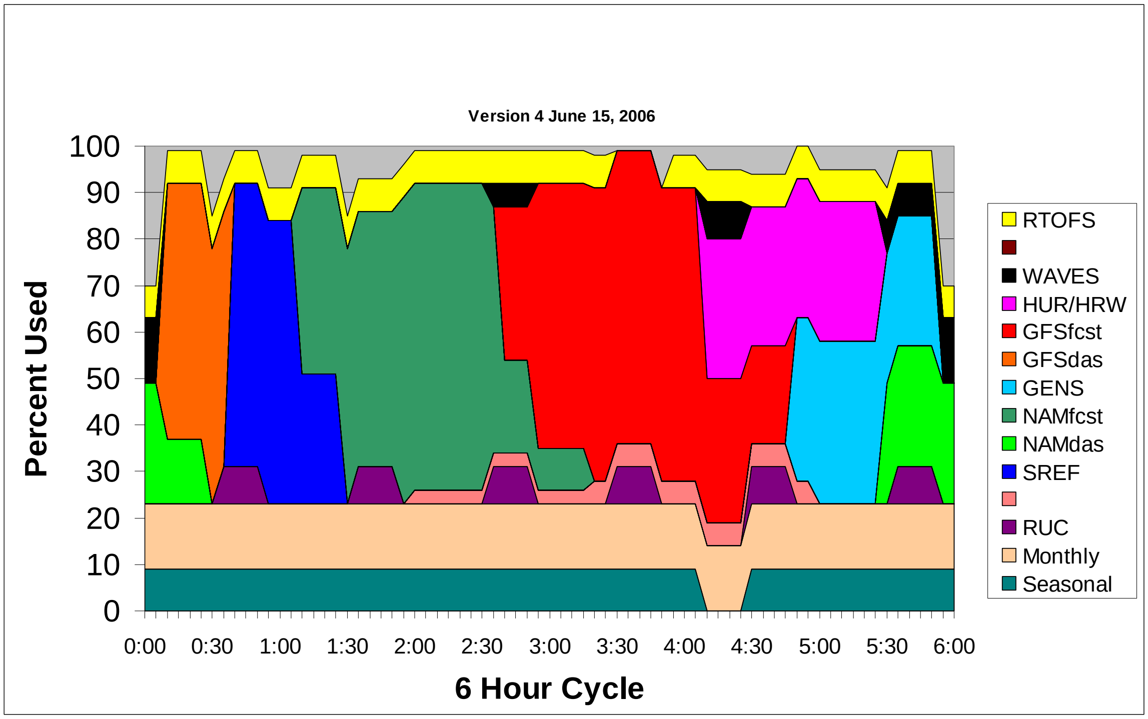
Table L-1. NextGen Requirements

Requirement					
Forecast System	Updates (per day)	Forecast Range (hours)	Forecast Start Time (minutes)	Delivery Time (minutes)	Horizontal Resolution (kilometers)
Final Operating Capability (FOC) 2025	FOC 2025	FOC 2025	FOC 2025	FOC 2025	FOC 2025
Global	8 (1 every 3 hours)	168 days 0–7	90	120	10
Global Long Range	8 (1 every 3 hours)	169–336 days 7–14	120	140	20
Regional	8 (1 every 3 hours)	60	95	120	6
En Route Nests CONUS & AK	24 hourly	60	15	30	2.5
Terminal x 55+	96 (1 every 15 minutes)	4	3	8	1

The following discussion and spreadsheets cover delivery of the seven-day forecast, which is performed at the highest resolution and places the largest demand on computer resources. The remaining forecast, from Day 7 through Day 16, will be delivered 20 minutes after the Day 7 forecast is delivered. The remaining forecast will have been downscaled to the target 10-km resolution for consistency with the first seven days of global forecast.

Figure L-1 illustrates the National Center for Environmental Prediction's (NCEP) current use of the production component of its Central Computing System (CCS).

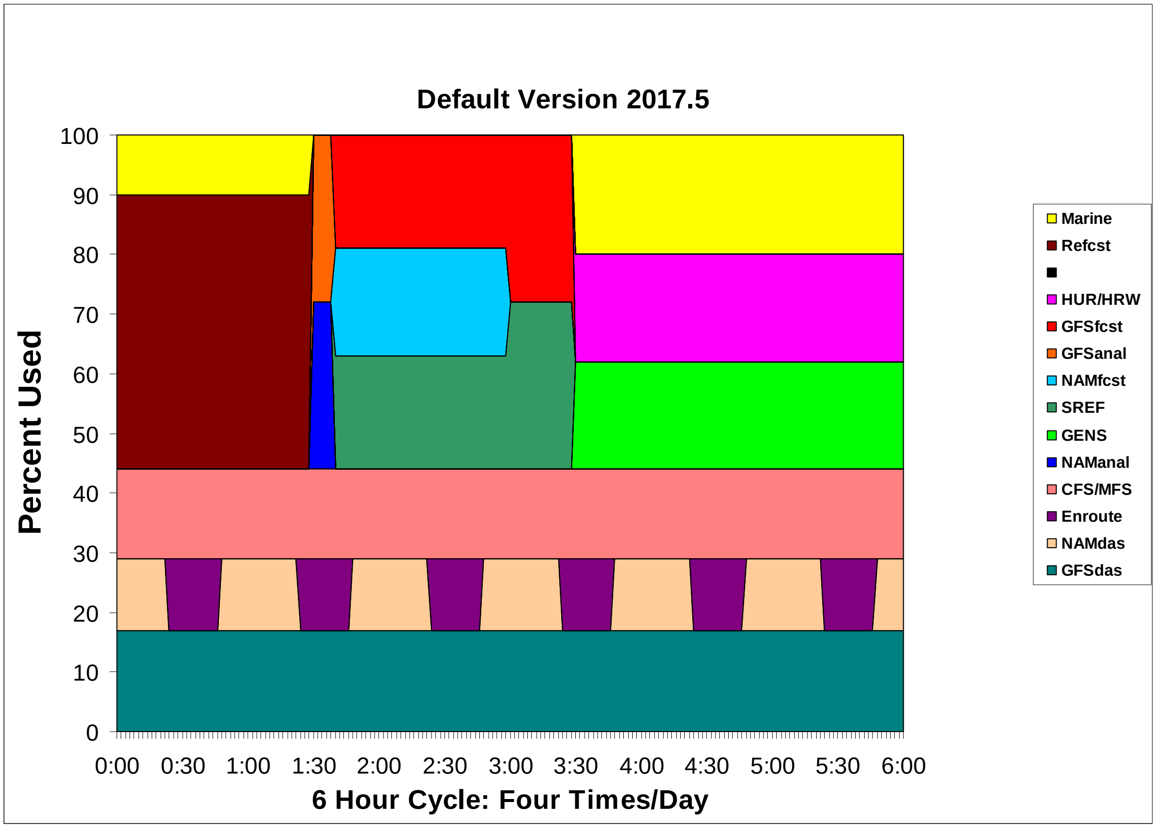
Figure L-1. NCEP Production Suite of Weather, Ocean, and Climate Forecast Systems



Modeling and data assimilation systems are run almost sequentially, and the same suite is run four times per day.

In Figure L-2, a future (~2017.5) configuration is depicted based on default funding.

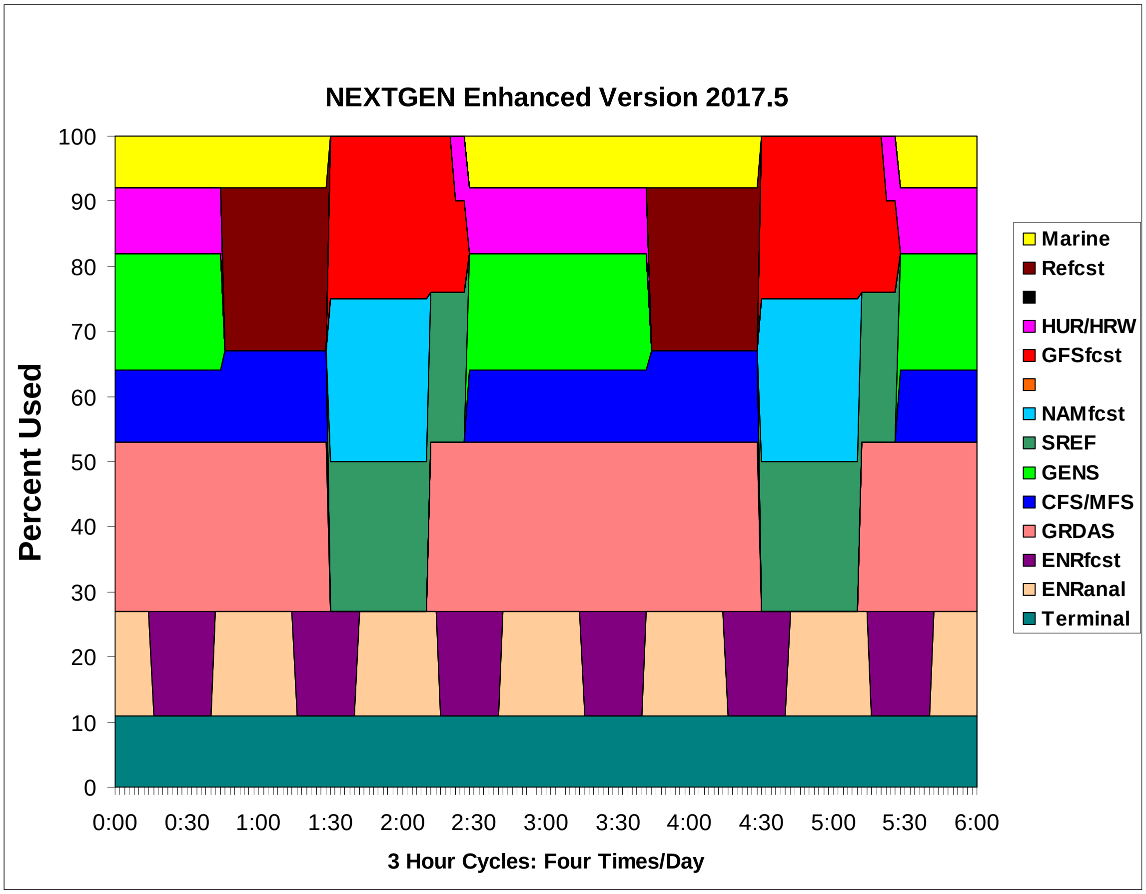
Figure L-2. NCEP Production Suite of Weather, Ocean, and Climate Forecast Systems



The primary difference between Figure L-2 and Figure L-1 is that in Figure L-2 the Global Forecasting System (GFS), North American Mesoscale (NAM), and Short-Range Ensemble Forecast (SREF) are all run concurrently, and the process of re-forecasting (used to calibrate ensembles) has begun.

In Figure L-3, a future (~2017.5) configuration is depicted, but with the benefit of a $30 million budget enhancement.

Figure L-3. NCEP Production Suite of Weather, Ocean, and Climate Forecast Systems



The challenge of performing three-hour updates is demonstrated. To run the demanding GFS, NAM, and SREF concurrently (even with additional computing provided by the enhancement), the Climate Forecast System (CFS) and Monthly Forecast System (MFS) runs must be suspended. In addition, the three-hour update also requires that these runs be finished within a shorter time.

In Table L-2, the additional cost of meeting the NextGen requirements are estimated to be $30 million. As demonstrated, it is required to push the NCEP update cycle for GFS and NAM from four per day (every six hours) to eight per day to run the en route continental United States (CONUS) and Alaska runs to 60 hours to allow terminal forecast. Table L-2 describes what is covered in the current $20 million budget, and in the additional $30 million. Facility expenses could be considerably higher.

Table L-2. Budget Costs

Current Computing Budget $20 million per year covers:	CPUs and Memory	Interconnect Fabric	Oper-ating System	File System	Software and Licenses	Disks and Controllers	System Administration	Appli-cation Specialists	Communications
Additional $20 million per year to cover	CPUs and Memory	Interconnect Fabric	Oper-ating System	File System	Software and Licenses	Disks and Controllers	System Administration	Appli-cation Specialists	Communications
Additional $5 million for facility expenses	Floor Space	Power	Heating	Cooling	Building Security	Extra Communications Infrastructure			
Additional $1.5 million for IT security		Currently 7.5%							
Additional $2.1 million for EMC development personnel									
Additional $1.4 million for NCO O&M personnel									

In Table L-3, the computer capability has been projected out through seven upgrades to 2025, based on past experience (no contractual commitments have been made beyond 2010) and a constant budget of ~$20 million. Based on an estimate of need for an annual increase of $30 million to meet NextGen requirements, these will be called a default and an enhanced scenario (see Table L-3).

Table L-3. Default and Enhanced Scenario

	2007	2010	2012.5	2015	2017.5	2020	2022.5	2025
Default Factor of increase in computing based on $20 million per year		3	2.5	2.5	2.5	2.5	2.5	2.5
Accumulated Factor	1	3	7.5	18.8	46.9	117.2	293.0	732.4
Accumulated Factor with additional $25 million starting in 2010	1	3	15	37.5	93.8	234.4	585.9	1464.8

Dr. DiMego shows the current percent usage of the machine by the 11 major components and projected that forward for the default (see Table L-4) and enhanced scenarios (see Table L-5).

Table L-4. Default Fraction of Machine Used

Default Fraction of Machine Used in Percent								
	2007	2010	2012.5	2015	2017.5	2020	2022.5	2025
GRDAS: global and regional data assimilation	10	12	16	20	24	24	21	21
GFS: global forecast system	17	15	12	9	7	7	6	6
GENS: global ensemble system	7	7	8	8	8	8	12	12
NAM: regional forecast	14	9	6	5	5	5	4	4
SREF: short-range ensemble forecasts	7	7	7	7	7	7	8	8
ENR: en route CONUS and Alaskan nests/ensembles	5	7	7	7	6	6	6	6
Terminal runs	0	0	0	0	0	0	0	0
Hurricane ensembles	7	7	7	7	7	7	7	7
Marine (wave and ocean ensembles)	9	9	10	10	10	10	10	10
CFS/MFS (seasonal and monthly ensembles)	24	22	19	17	15	15	15	15
ReFORECASTs	0	5	8	10	11	11	11	11

Table L-5. NextGen-Enhanced Fraction of Machine Used

NextGen-Enhanced Fraction of Machine Used in Percent								
	2007	2010	2012.5	2015	2017.5	2020	2022.5	2025
GRDAS: global and regional data assimilation	10	12	16	20	20	20	20	20
GFS: global forecast system	17	14	11	9	8	7	6	6
GENS: global ensemble system	7	7	8	8	8	9	11	11
NAM: regional forecast	14	10	8	6	6	5	4	4
SREF: Short range ensemble forecasts	7	7	7	7	7	8	8	8
ENR: en route CONUS and Alaskan nests/ensembles	5	7	16	16	16	16	16	16
Terminal runs	0	0	11	11	11	11	11	11
Hurricane ensembles	7	7	5	5	5	5	5	5
Marine (wave and ocean ensembles)	9	9	5	5	5	5	5	5
CFS/MFS (seasonal and monthly ensembles)	24	22	8	8	8	8	8	8
ReFORECASTs	0	5	5	5	6	6	6	6

In turn, these were used to estimate available computer power under the two scenarios (not reproduced here). It is assumed that the additional funding would be available in 2010, which would result in increased computer capability initially available with the 2012.5 upgrade.

Using these estimates, Table L-6 shows the evolution of the four components of NCEP's production suite that most closely match those in Table L-1 and demonstrates (roughly) where NCEP would be without the NextGen requirements and enhancement.

Note that although all four components meet target resolutions, updates are performed only every six hours for GFS and NAM, en route runs are only to a 12-hour range, and terminal runs are totally undependable during hurricane season and very untimely even when they do run.

Table L-7 shows not only the evolution of the four components of NCEP's production suite that most closely match those in Table L-1, but also (roughly) where NCEP would be with the NextGen enhancement of $30 million annually starting in 2010 and meeting all NextGen requirements listed in Section 4.

Table L-6. Evolution With No Increase in Funding

Evolution With *No* Increase in Funding					
Forecast System	Updates (per day)	Forecast Range (hours)	Forecast Start Time (minutes)	Delivery Time (minutes)	Horizontal Resolution
	2010	2010	2010	2010	2010
GLOBAL GFS	4	168	200	245	35
	2012.5	2012.5	2012.5	2012.5	2012.5
GLOBAL GFS	4	168	200	245	28
	2015	2015	2015	2015	2015
GLOBAL GFS	4	168	200	243	23
	2017.5	2017.5	2017.5	2017.5	2017.5
GLOBAL GFS	4	168	200	245	19
	2020	2020	2020	2020	2020
GLOBAL GFS	4	168	200	245	15
	2022.5	2022.5	2022.5	2022.5	2022.5
GLOBAL GFS	4	168	200	245	12
	2025	2025	2025	2025	2025
GLOBAL GFS	4	168	200	245	10
	2010	2010	2010	2010	2010
Regional NAM	4	60	90	140	12
	2012.5	2012.5	2012.5	2012.5	2012.5
Regional NAM	4	60	90	140	11
	2015	2015	2015	2015	2015
Regional NAM	4	60	90	140	10
	2017.5	2017.5	2017.5	2017.5	2017.5
Regional NAM	4	60	90	135	9
	2020	2020	2020	2020	2020
Regional NAM	4	60	90	130	8
	2022.5	2022.5	2022.5	2022.5	2022.5
Regional NAM	4	60	90	125	7
	2025	2025	2025	2025	2025
Regional NAM	4	60	90	120	6
	2010	2010	2010	2010	2010
En Route Nests CONUS&AK	24	12	25	60	6
	2012.5	2012.5	2012.5	2012.5	2012.5
En Route Nests CONUS&AK	24	12	25	45	5.5
	2015	2015	2015	2015	2015
En Route Nests CONUS&AK	24	12	25	45	4.5
	2017.5	2017.5	2017.5	2017.5	2017.5
En Route Nests CONUS&AK	24	12	25	45	4

Evolution With *No* Increase in Funding					
Forecast System	**Updates (per day)**	**Forecast Range (hours)**	**Forecast Start Time (minutes)**	**Delivery Time (minutes)**	**Horizontal Resolution**
	2020	2020	2020	2020	2020
En Route Nests CONUS&AK	24	12	25	45	3.5
	2022.5	2022.5	2022.5	2022.5	2022.5
En Route Nests CONUS & AK	24	12	25	45	3
	2025	2025	2025	2025	2025
En Route Nests CONUS & AK	24	12	25	45	2.5
No DEPENDABLE Terminal Runs					
	2010	2010	2010	2010	2010
Terminal (HRW) Run	4	4	344	350	3.75
	2012.5	2012.5	2012.5	2012.5	2012.5
Terminal (HRW) Run	4	4	344	350	3
	2015	2015	2015	2015	2015
Terminal (HRW) Run	4	4	344	350	2.5
	2017.5	2017.5	2017.5	2017.5	2017.5
Terminal (HRW) Run	4	4	344	350	2
	2020	2020	2020	2020	2020
Terminal (HRW) Run	4	4	344	350	1.6
	2022.5	2022.5	2022.5	2022.5	2022.5
Terminal (HRW) Run	4	4	344	350	1.3
	2025	2025	2025	2025	2025
Terminal (HRW) Run	4	4	344	350	1

Table L-7. Evolution with $30 Million Increase in Funding, Starting in 2010

Evolution with $30 Million Increase in Funding, Starting in 2010					
Forecast System	Updates per day	Forecast Range in Hours	Forecast Start Time Minutes	Delivery Time in minutes	Horizontal Resolution
	2010	2010	2010	2010	2010
GLOBAL GFS	4	168	200	245	35
	2012.5	**2012.5**	**2012.5**	**2012.5**	**2012.5**
GLOBAL GFS	8	168	200	245	28
	2015	2015	2015	2015	2015
GLOBAL GFS	8	168	90	135	23
	2017.5	2017.5	2017.5	2017.5	2017.5
GLOBAL GFS	8	168	200	245	19
	2020	2020	2020	2020	2020
GLOBAL GFS	8	168	200	245	15
	2022.5	2022.5	2022.5	2022.5	2022.5
GLOBAL GFS	8	168	200	245	12
	2025	2025	2025	2025	2025
GLOBAL GFS	8	168	200	245	10
	2010	2010	2010	2010	2010
Regional NAM	4	60	90	140	12
	2012.5	**2012.5**	**2012.5**	**2012.5**	**2012.5**
Regional NAM	8	60	90	140	11
	2015	2015	2015	2015	2015
Regional NAM	8	60	90	135	10
	2017.5	2017.5	2017.5	2017.5	2017.5
Regional NAM	8	60	95	135	9
	2020	2020	2020	2020	2020
Regional NAM	8	60	95	130	8
	2022.5	2022.5	2022.5	2022.5	2022.5
Regional NAM	8	60	95	125	7
	2025	2025	2025	2025	2025
Regional NAM	8	60	95	120	6
	2010	2010	2010	2010	2010
En Route Nests CONUS & AK	24	12	25	60	6
	2012.5	**2012.5**	**2012.5**	**2012.5**	**2012.5**
En Route Nests CONUS & AK	24	60	25	50	5.5
	2015	2015	2015	2015	2015
En Route Nests CONUS & AK	24	60	25	50	4.5
	2017.5	2017.5	2017.5	2017.5	2017.5
En Route	24	60	25	45	4

Evolution with $30 Million Increase in Funding, Starting in 2010					
Forecast System	Updates per day	Forecast Range in Hours	Forecast Start Time Minutes	Delivery Time in minutes	Horizontal Resolution
Nests CONUS & AK					
	2020	2020	2020	2020	2020
En Route Nests CONUS & AK	24	60	20	35	3.5
	2022.5	2022.5	2022.5	2022.5	2022.5
En Route Nests CONUS & AK	24	60	20	35	3
	2025	2025	2025	2025	2025
En Route Nests CONUS & AK	24	60	15	30	2.5

APPENDIX M. DRAFT 4-D WEATHER DATA CUBE FUNCTIONAL REQUIREMENTS BASED ON THE FUNCTIONS SHOWN IN APPENDIX B

The draft functional requirements in Appendix M are for the 4-D Wx Data Cube, not the 4-D Wx SAS. They were developed using the functions determined by the team. Each function was transformed into a functional requirement. For example, function F1.1.1.1.1.9.2 in Appendix B is "Calculate Sea Level Pressure," which translated into "The NextGen shall calculate sea level pressure in hectopascals."

The JPDO Wx Working Group decided that the development of the performance requirements would be spread across multiple study teams. The functional requirements study team chose to develop a draft set of NextGen weather functional requirements to aid them in writing these performance requirements.

Table M-1. Draft Functional Requirements for the Function "Observe Atmospheric and Space Conditions"

The NextGen shall observe atmospheric and space conditions.
The NextGen shall observe atmospheric conditions.
The NextGen shall observe present surface weather.
The NextGen shall observe surface liquid precipitation.
The NextGen shall measure the intensity of liquid precipitation.
The NextGen shall determine liquid precipitation type.
The NextGen shall determine the location of rain.
The NextGen shall calculate rain intensity.
The NextGen shall determine rainfall rate in inches per hour.
The NextGen shall determine the location of rain showers.
The NextGen shall calculate the rain shower intensity.
The NextGen shall measure the accumulation of liquid precipitation.
The NextGen shall determine the beginning time of liquid precipitation.
The NextGen shall determine the ending time of liquid precipitation.
The NextGen shall determine the direction of movement of liquid precipitation in degrees to the nearest 10 degrees.
The NextGen shall determine the speed of movement of liquid precipitation in nautical miles per hour.
The NextGen shall observe solid precipitation.
The NextGen shall measure the intensity of solid precipitation.
The NextGen shall determine solid precipitation type.
The NextGen shall determine the location of hail.
The NextGen shall determine the horizontal extent of hail.
The NextGen shall estimate the size of largest hailstone in inches.
The NextGen shall determine the location of hail showers.
The NextGen shall determine the location of snow.
The NextGen shall determine the horizontal extent of snow.
The NextGen shall measure snowfall rate in inches/hour.

The NextGen shall measure snowfall accumulation in inches.
The NextGen shall measure snowfall intensity.
The NextGen shall determine snowfall beginning time.
The NextGen shall determine snowfall ending time.
The NextGen shall calculate the liquid water equivalent of snowfall in inches per hour.
The NextGen shall determine the location of snow showers.
The NextGen shall observe ice crystals.
The NextGen shall determine the location of ice crystals.
The NextGen shall determine the horizontal extent of ice crystals.
The NextGen shall observe ice pellets.
The NextGen shall determine the location of ice pellets.
The NextGen shall determine the horizontal extent of ice pellets.
The NextGen shall determine the horizontal extent of ice pellets.
The NextGen shall measure ice pellet intensity.
The NextGen shall determine the beginning time of ice pellets.
The NextGen shall determine the ending time of ice pellets.
The NextGen shall observe snow grains.
The NextGen shall determine the location of snow grains.
The NextGen shall determine where snow is blowing in the terminal area.
The NextGen shall determine the location of low drifting snow.
The NextGen shall determine the location of small hail.
The NextGen shall determine the location of snow pellets.
The NextGen shall determine the beginning time of snow pellets.
The NextGen shall determine the ending time of snow pellets.
The NextGen shall observe surface freezing precipitation.
The NextGen shall determine the beginning time of surface freezing precipitation.
The NextGen shall determine the ending time of surface freezing precipitation.
The NextGen shall measure the intensity of freezing precipitation.
The NextGen shall determine the location of freezing rain.
The NextGen shall determine the horizontal extent of freezing rain.
The NextGen shall determine the location of freezing drizzle.
The NextGen shall determine the horizontal extent of freezing drizzle.
The NextGen shall determine the existence of surface icing conditions.
The NextGen shall determine the horizontal extent of surface icing conditions.
The NextGen shall determine the surface icing accretion rate in inches/hour.
The NextGen shall observe surface obscurations to visibility.
The NextGen shall determine the location of haze in the terminal area of designated airports.
The NextGen shall determine the location of smoke in the terminal area of designated airports.
The NextGen shall determine the location of mist in the terminal area of designated airports.
The NextGen shall determine the location of fog in the terminal area of designated airports.
The NextGen shall determine the location of shallow fog in the terminal area of designated airports.
The NextGen shall determine the location of fog patches in the terminal area of designated airports.

The NextGen shall determine the location of partial fog in the terminal area of designated airports.
The NextGen shall determine the location of freezing fog in the terminal area of designated airports.
The NextGen shall determine the location of blowing spray in the terminal area of designated airports.
The NextGen shall determine the location of blowing sand in the terminal area of designated airports.
The NextGen shall determine the location of low drifting sand in the terminal area of designated airports.
The NextGen shall determine the location of blowing snow in the terminal area of designated airports.
The NextGen shall determine the location of widespread dust.
The NextGen shall observe volcanic ash in the terminal area.
The NextGen shall determine the horizontal extent of volcanic ash.
The NextGen shall observe the volcanic ash plume.
The NextGen shall determine the maximum flight level of volcanic ash.
The NextGen shall determine the minimum flight level of volcanic ash.
The NextGen shall determine the volume of air containing volcanic ash.
The NextGen shall measure the density of volcanic ash.
The NextGen shall determine the layer(s) where volcanic ash is most concentrated.
The NextGen shall determine approach slant range visibility in statute miles at designated airports.
The NextGen shall observe thunderstorms.
The NextGen shall determine the location of thunderstorms.
The NextGen shall determine the beginning time of thunderstorms.
The NextGen shall determine the ending time of thunderstorms.
The NextGen shall measure the direction of thunderstorm movement in degrees to the nearest 10 degrees.
The NextGen shall measure the speed of thunderstorm movement in nautical miles per hour to the nearest 5 nautical miles per hour.
The NextGen shall determine thunderstorm intensity.
The NextGen shall determine the thunderstorm base in hundreds of feet.
The NextGen shall determine the thunderstorm top in hundreds of feet.
The NextGen shall determine the horizontal extent of thunderstorms.
The NextGen shall measure thunderstorm cell intensity.
The NextGen shall determine the thunderstorm cell locations.
The NextGen shall determine the location of thunderstorm initiation.
The NextGen shall determine the location of thunderstorm growth.
The NextGen shall determine the location of thunderstorm decay.
The NextGen shall determine the beginning time of thunderstorm cells.
The NextGen shall determine the ending time of thunderstorm cells.
The NextGen shall observe mesocyclones.
The NextGen shall determine the location of mesocyclones.

The NextGen shall measure the speed of mesocyclone movement in nautical miles per hour to the nearest 5 nautical miles per hour.
The NextGen shall measure the mesocyclone intensity.
The NextGen shall observe gust fronts.
The NextGen shall determine gust front location in relationship to runways.
The NextGen shall measure the direction of gust front movement in degrees to the nearest 10 degrees.
The NextGen shall measure the speed of gust front movement in nautical miles per hour.
The NextGen shall determine the time of gust front passage.
The NextGen shall observe lightning.
The NextGen shall observe cloud-to-ground lightning.
The NextGen shall observe inter-cloud lightning.
The NextGen shall observe intra-cloud lightning.
The NextGen shall determine the frequency of cloud-to ground lightning.
The NextGen shall determine the frequency of inter-cloud lightning.
The NextGen shall determine the frequency of intra-cloud lightning.
The NextGen shall determine the beginning time of lightning.
The NextGen shall determine the ending time of lightning.
The NextGen shall observe low level wind shear.
The NextGen shall determine the location of low level wind shear.
The NextGen shall determine the minimum flight altitude of low level wind shear.
The NextGen shall determine the maximum flight altitude of low level wind shear.
The NextGen shall measure the airspeed gain and loss due to low level wind shear in nautical miles per hour.
The NextGen shall determine the direction of movement of low level wind shear in degrees to the nearest 10 degrees.
The NextGen shall determine the speed of movement of low level wind shear in nautical miles per hour.
The NextGen shall determine the beginning time of low level wind shear.
The NextGen shall determine the ending time of low level wind shear.
The NextGen shall observe microbursts.
The NextGen shall determine the location of microbursts.
The NextGen shall measure the airspeed gain and loss due to microbursts in nautical miles per hour.
The NextGen shall determine the direction of movement of microbursts in degrees to the nearest 10 degrees.
The NextGen shall determine the speed of movement of microbursts in nautical miles per hour.
The NextGen shall determine the beginning time of microbursts.
The NextGen shall determine the ending time of microbursts.
The NextGen shall observe squalls.
The NextGen shall determine the location of squalls.
The NextGen shall measure the direction of squall movement in degrees to the nearest 10 degrees.
The NextGen shall measure the speed of squall movement in nautical miles per hour to the nearest 5 nautical miles per hour.

The NextGen shall determine the beginning time of squalls.
The NextGen shall determine the ending time of squalls.
The NextGen shall observe tornadic activity.
The NextGen shall determine funnel cloud location.
The NextGen shall measure the funnel cloud speed of movement in nautical miles per hour to the nearest 5 nautical miles per hour.
The NextGen shall measure the funnel cloud direction of movement in degrees to the nearest 10 degrees.
The NextGen shall determine the funnel cloud intensity.
The NextGen shall determine the funnel cloud beginning time.
The NextGen shall determine the funnel cloud ending time.
The NextGen shall measure funnel cloud intensity.
The NextGen shall determine tornado location.
The NextGen shall measure the tornado speed of movement in nautical miles per hour to the nearest 5 nautical miles per hour.
The NextGen shall measure the tornado direction of movement in degrees to the nearest 10 degrees.
The NextGen shall determine the tornado beginning time.
The NextGen shall determine the tornado ending time.
The NextGen shall measure tornado intensity in the Fujita scale values.
The NextGen shall determine the height of the tornado cloud base.
The NextGen shall determine water spout location.
The NextGen shall measure the water spout speed of movement in nautical miles per hour to the nearest 5 nautical miles per hour.
The NextGen shall measure the water spout direction of movement in degrees to the nearest 10 degrees
The NextGen shall determine the water spout beginning time.
The NextGen shall determine the water spout ending time.
The NextGen shall measure water spout intensity.
The NextGen shall observe wake vortex at designated airports.
The NextGen shall determine wake vortex location.
The NextGen shall determine wake vortex horizontal displacement.
The NextGen shall determine wake vortex vertical displacement.
The NextGen shall determine wake vortex dissipation.
The NextGen shall observe well developed dust/sand whirls.
The NextGen shall determine the location of well-developed dust/sand whirls.
The NextGen shall determine the well-developed dust/sand whirls beginning time.
The NextGen shall determine the well-developed dust/sand whirls ending time.
The NextGen shall observe dust storms.
The NextGen shall determine the location of dust storms.
The NextGen shall determine the dust storm beginning time.
The NextGen shall determine the dust storm ending time.
The NextGen shall observe sand storms.
The NextGen shall determine the location of sandstorms.
The NextGen shall determine the sand storm beginning time.

The NextGen shall determine the sand storm ending time.
The NextGen shall determine the location of fog banks.
The NextGen shall observe frost.
The NextGen shall determine the horizontal extent of frost.
The NextGen shall determine the beginning time of frost.
The NextGen shall determine the ending time of frost.
The NextGen shall observe weather conditions that contribute to reduce braking action.
The NextGen shall observe wind direction from the surface to the top of the NAS.
The NextGen shall observe wind speed from the surface to the top of the NAS.
The NextGen shall measure the wind direction in degrees to the nearest 10 degrees.
The NextGen shall measure the wind speed in nautical miles per hour.
The NextGen shall determine variable wind direction in degrees to the nearest 10 degrees.
The NextGen shall determine variable wind speed in nautical miles per hour.
The NextGen shall determine the occurrence of wind gusts.
The NextGen shall measure the wind gust direction in degrees to the nearest 10 degrees.
The NextGen shall measure the wind gust speed in nautical miles per hour.
The NextGen shall determine the time of the wind gust.
The NextGen shall determine the airport wind.
The NextGen shall measure the airport wind direction in degrees to the nearest 10 degrees.
The NextGen shall measure the airport wind speed in nautical miles per hour.
The NextGen shall determine the occurrence of wind shifts at designated airports.
The NextGen shall calculate the time of wind shift.
The NextGen shall determine the occurrence of a peak wind.
The NextGen shall measure the peak wind direction in degrees to the nearest 10 degrees.
The NextGen shall measure the peak wind speed in nautical miles per hour.
The NextGen shall determine the time of peak wind.
The NextGen shall determine calm wind.
The NextGen shall determine runway winds.
The NextGen shall measure the runway threshold wind direction in degrees to the nearest 10 degrees.
The NextGen shall measure the runway threshold wind speed in nautical miles per hour.
The NextGen shall measure the runway midpoint wind direction in degrees to the nearest 10 degrees.
The NextGen shall measure the runway midpoint wind speed in nautical miles per hour.
The NextGen shall measure the runway departure wind direction in degrees to the nearest 10 degrees.
The NextGen shall measure the runway departure wind speed in nautical miles per hour.
The NextGen shall observe surface visibility.
The NextGen shall measure surface visibility in statute miles.
The NextGen shall measure tower visibility in statute miles.
The NextGen shall determine the airport visibility.
The NextGen shall determine the prevailing visibility.
The NextGen shall determine variable prevailing visibility.
The NextGen shall determine sector visibility.
The NextGen shall measure sector visibility in statute miles.

The NextGen shall observe runway visual range.
The NextGen shall measure the runway visual range in feet at touchdown.
The NextGen shall measure the runway visual range in feet at midpoint.
The NextGen shall measure the runway visual range in feet at rollout.
The NextGen shall calculate the runway visual range 10-minute average in feet.
The NextGen shall observe pressure parameters.
The NextGen shall observe barometric pressure in hundreds of inch of mercury.
The NextGen shall calculate the sea level pressure in hectopascals.
The NextGen shall calculate the station pressure in hundreds of inch of mercury.
The NextGen shall calculate pressure change in hundreds of inch of mercury.
The NextGen shall calculate the pressure tendency
The NextGen shall determine pressure rising rapidly in hundreds of inch of mercury per hour.
The NextGen shall determine pressure falling rapidly in hundreds of inch of mercury per hour.
The NextGen shall calculate the 3-hour pressure tendency.
The NextGen shall calculate the station altimeter setting in.
The NextGen shall calculate the station density altitude.
The NextGen shall observe sky conditions.
The NextGen shall determine the sky cover.
The NextGen shall measure each cloud layer height.
The NextGen shall determine the lowest “few” cloud layer.
The NextGen shall determine the lowest “broken” cloud layer.
The NextGen shall determine overcast cloud layers.
The NextGen shall determine the lowest “scattered” cloud layer.
The NextGen shall determine the second lowest “scattered” cloud layer.
The NextGen shall determine the second lowest “broken” cloud layer.
The NextGen shall determine the highest “scattered” cloud layer.
The NextGen shall determine the highest “broken” cloud layer.
The NextGen shall determine the existence of a cloud ceiling.
The NextGen shall measure cloud ceiling height.
The NextGen shall determine cloud type.
The NextGen shall determine variable cloud ceiling.
The NextGen shall determine the maximum altitude of cloud tops.
The NextGen shall observe the airport surface temperature.
The NextGen shall measure the surface temperature.
The NextGen shall determine the surface maximum temperature.
The NextGen shall measure the surface dew point temperature.
The NextGen shall determine the surface minimum temperature.
The NextGen shall measure the runway surface temperature.
The NextGen shall observe dew point temperature from the surface to the top of the NAS.
The NextGen shall observe the temperature from surface to top of the NAS.
The NextGen shall observe the ocean surface conditions.
The NextGen shall measure ocean wave height in feet.
The NextGen shall measure ocean wave direction in degrees to the nearest 10 degrees.
The NextGen shall measure ocean swell height in feet.
The NextGen shall measure ocean swell direction in degrees to the nearest 10 degrees.

The NextGen shall observe the large lake surface conditions.
The NextGen shall measure large lake wave height in feet.
The NextGen shall measure large lake wave direction in degrees to the nearest 10 degrees.
The NextGen shall measure large lake swell height in feet.
The NextGen shall measure large lake swell direction in degrees to the nearest 10 degrees.
The NextGen shall determine compression[1] winds from surface to the top of the terminal airspace at designated airport.
The NextGen shall observe the location of obscuration to visibility aloft.
The NextGen shall determine the location of smoke aloft.
The NextGen shall determine the location of blowing dust aloft.
The NextGen shall observe weather aloft.
The NextGen shall measure moisture from surface to top of NAS.
The NextGen shall observe precipitation aloft.
The NextGen shall observe liquid precipitation aloft.
The NextGen shall observe solid precipitation aloft.
The NextGen shall determine the flight levels with the occurrence of rain.
The NextGen shall observe drizzle from surface to top of the NAS.
The NextGen shall determine the location of drizzle.
The NextGen shall determine the horizontal extent of drizzle.
The NextGen shall determine the flight levels with the occurrence of drizzle.
The NextGen shall observe virga.
The NextGen shall determine the location of virga.
The NextGen shall determine the flight levels with the occurrence of hail.
The NextGen shall determine the flight levels with the occurrence of snow.
The NextGen shall determine the flight levels with the occurrence of ice pellets.
The NextGen shall determine the flight levels with the occurrence of ice crystals.
The NextGen shall observe freezing precipitation aloft.
The NextGen shall determine the flight levels with the occurrence of freezing drizzle.
The NextGen shall determine the flight levels with the occurrence of freezing rain.
The NextGen shall determine the altitude of freezing level.
The NextGen shall determine the horizontal extent of super cooled liquid droplets.
The NextGen shall determine the flight levels with super cooled liquid droplets.
The NextGen shall determine the flight level of thunderstorm cloud tops.
The NextGen shall determine the minimum altitude of thunderstorm cloud bases.
The NextGen shall observe in-flight icing.
The NextGen shall determine the location of in-flight icing.
The NextGen shall determine the flight levels of in-flight icing.
The NextGen shall determine the type of in-flight icing.
The NextGen shall observe turbulence.
The NextGen shall determine the location of turbulence.
The NextGen shall determine the flight levels of turbulence.
The NextGen shall measure the intensity of turbulence in eddy dissipation rate.

[1] Compression Winds—Related to wind change in speed/direction with height over/near airports; vertical wind profile

Table M-2. Draft Functional Requirements for the Function “Observe Space Conditions”

The NextGen shall observe solar radiation activity.
The NextGen shall observe solar flares.
The NextGen shall observe coronal mass ejections.
The NextGen shall determine magnitude of solar radiation affecting aviation.
The NextGen shall determine the time of onset of solar radiation affecting aviation.
The NextGen shall calculate the duration of solar radiation affecting aviation.
The NextGen shall observe regions of high energy of solar radiation.
The NextGen shall determine the regions of high energy (> 10 MeV) of solar radiation.
The NextGen shall determine the regions of high energy (> 100 MeV) of solar radiation.
The NextGen shall observe geomagnetic storm activity.
The NextGen shall determine location of geomagnetic storm activity.
The NextGen shall determine onset of geomagnetic storm activity.
The NextGen shall determine duration of geomagnetic storm activity.

Table M-3. Draft Functional Requirements for the Function "Forecast Weather"

The NextGen shall forecast atmospheric and space conditions.
The NextGen shall forecast the beginning time of atmospheric and space conditions. (WP)
The NextGen shall forecast the ending time of atmospheric and space conditions.
The NextGen shall forecast the location of atmospheric and space conditions
The NextGen shall forecast surface weather.
The NextGen shall forecast terminal instrument flight rules (IFR) conditions. (WP)**
The NextGen shall forecast frost. (WP)
The NextGen shall forecast the horizontal extent of frost. (WP)
The NextGen shall forecast wind direction from the surface to the top of the NAS.
The NextGen shall forecast wind speed from the surface to the top of the NAS.
The NextGen shall forecast the wind direction in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast the wind speed in nautical miles per hour. (WP)
The NextGen shall forecast the probability distribution of wind speed.
The NextGen shall forecast the occurrence of variable winds. (WP)
The NextGen shall forecast variable wind direction in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast variable wind speed in nautical miles per hour. (WP)
The NextGen shall forecast the occurrence of wind shifts at designated airports*. (WP)
The NextGen shall forecast the duration of wind shifts. (WP)
The NextGen shall forecast the location of peak winds. (WP)
The NextGen shall forecast the peak wind direction in degrees to the nearest 10 degrees.
The NextGen shall forecast the peak wind speed in nautical miles per hour.
The NextGen shall forecast the location of wind gusts. (WP)
The NextGen shall forecast the wind gust direction in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast the wind gust speed in nautical miles per hour. (WP)
The NextGen shall forecast runway winds. (WP)
The NextGen shall forecast the runway threshold wind direction in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast the runway threshold wind speed in nautical miles per hour. (WP)
The NextGen shall forecast the runway departure wind direction in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast the runway departure wind speed in nautical miles per hour. (WP)
The NextGen shall forecast the probability distribution function of terminal instrument flight rules (IFR) conditions.
The NextGen shall forecast compression[2] winds from surface to the top of the terminal airspace at designated airports*.
The NextGen shall forecast the airport surface temperature. (WP)
The NextGen shall forecast the surface maximum temperature. (WP)
The NextGen shall forecast the probability distribution function of maximum temperature.
The NextGen shall forecast the surface dew point temperature.
The NextGen shall forecast the surface minimum temperature.
The NextGen shall forecast the runway surface temperature. (WP)

[2] Compression Winds—Related to wind change in speed/direction with height over/near airports; vertical wind profile

The NextGen shall forecast relative humidity from the surface to top of NAS.
The NextGen shall forecast the temperature from the surface to the top of the NAS.
The NextGen shall forecast the dew point temperature from the surface to the top of the NAS.
The NextGen shall forecast the surface relative humidity.
The NextGen shall forecast surface obscurations to visibility. (WP)
The NextGen shall forecast areas of widespread low visibility. (WP)
The NextGen shall forecast obscurations less than 6,000 feet above ground level for areas beyond the airport. (WP)
The NextGen shall forecast vertical extent of surface obscuration at designated airports*. (WP)
The NextGen shall forecast horizontal extent of surface obscuration at designated airports. (WP)
The NextGen shall forecast haze in the terminal area of designated airports. (WP)
The NextGen shall forecast smoke in the terminal area of designated airports.
The NextGen shall forecast mist in the terminal area of designated airports.
The NextGen shall forecast fog in the terminal area of designated airports. (WP)
The NextGen shall forecast blowing snow in the terminal area of designated airports.
The NextGen shall forecast blowing spray in the terminal area of designated airports.
The NextGen shall forecast freezing fog in the terminal area of designated airports. (WP)
The NextGen shall forecast blowing sand in the terminal area of designated airports.
The NextGen shall forecast low drifting sand in the terminal area of designated airports.
The NextGen shall forecast widespread dust in the terminal area of designated airports.
The NextGen shall forecast low clouds in the terminal area of designated airports. (WP)
The NextGen shall forecast cloud ceilings at designated airports. (WP)
The NextGen shall forecast cloud ceiling height. (WP)
The NextGen shall forecast cloud type.
The NextGen shall forecast each cloud layer height.
The NextGen shall forecast cloud layer thickness. (WP)
The NextGen shall forecast the height of the dominant cloud layer base. (WP)
The NextGen shall forecast the horizontal extent of cloud ceilings.
The NextGen shall forecast the maximum altitude of cloud tops. (WP)
The NextGen shall forecast liquid precipitation.
The NextGen shall forecast the horizontal extent of liquid precipitation.
The NextGen shall forecast the accumulation of liquid precipitation in inches. (WP)
The NextGen shall forecast rain intensity. (WP)
The NextGen shall forecast occurrence of moderate or greater rain showers. (WP)
The NextGen shall forecast direction of liquid precipitation movement in degrees to the nearest 10 degrees.
The NextGen shall forecast speed of liquid precipitation movement in nautical miles per hour.
The NextGen shall forecast freezing precipitation type. (WP)
The NextGen shall forecast freezing rain. (WP)
The NextGen shall forecast the location of freezing rain. (WP)
The NextGen shall forecast the horizontal extent of freezing rain. (WP)
The NextGen shall forecast freezing drizzle. (WP)
The NextGen shall forecast the location of freezing drizzle. (WP)
The NextGen shall forecast the horizontal extent of freezing drizzle. (WP)
The NextGen shall forecast the probability distribution function of freezing precipitation.

The NextGen shall forecast ice accretion rate in inches. (WP)
The NextGen shall forecast surface icing accumulation. (WP)
The NextGen shall forecast solid precipitation.
The NextGen shall forecast snow. (WP)
The NextGen shall forecast snow intensity. (WP)
The NextGen shall forecast snowfall rate in inches per hour. (WP)
The NextGen shall forecast snow accumulation in inches. (WP)
The NextGen shall forecast snow showers. (WP)
The NextGen shall forecast the liquid water equivalent of snowfall accumulation. (WP)
The NextGen shall forecast hail. (WP)
The NextGen shall forecast hail size of ½ inch or greater. (WP)
The NextGen shall forecast the horizontal extent of hail. (WP)
The NextGen shall forecast ice pellets. (WP)
The NextGen shall forecast the horizontal extent of ice pellets.
The NextGen shall forecast ice pellet intensity. (WP)
The NextGen shall forecast snow pellets. (WP)
The NextGen shall forecast ice crystals. (WP)
The NextGen shall forecast the liquid water equivalent of solid precipitation inches per hour. (WP)
The NextGen shall forecast surface visibility in statute miles. (WP)
The NextGen shall forecast the airport visibility in statute miles. (WP)
The NextGen shall forecast runway visual range 10-minute average. (WP)
The NextGen shall forecast the airport wind.
The NextGen shall forecast the airport wind direction in degrees to the nearest 10 degrees.
The NextGen shall forecast the airport wind speed in nautical miles per hour.
The NextGen shall forecast precipitation aloft.
The NextGen shall forecast volcanic ash in the terminal area of designated airports. (WP)
The NextGen shall forecast the horizontal extent of volcanic ash. (WP)
The NextGen shall forecast the volcanic ash plume. (WP)
The NextGen shall forecast the maximum flight level of volcanic ash. (WP)
The NextGen shall forecast the minimum flight level of volcanic ash. (WP)
The NextGen shall forecast the density of volcanic ash.
The NextGen shall forecast the layer(s) where volcanic ash is most concentrated.
The NextGen shall forecast the location of obscuration to visibility aloft.
The NextGen shall forecast the ocean surface conditions for the NAS.
The NextGen shall forecast ocean wave height in feet. (WP)
The NextGen shall forecast ocean wave direction in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast ocean swell height in feet. (WP)
The NextGen shall forecast ocean swell direction in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast the large lake surface conditions.
The NextGen shall forecast the position of the jet stream out to 48 hours for the NAS.
The NextGen shall forecast wind compression profile to 25,000 feet for designated airports.
The NextGen shall forecast vertical wind profile up to 100,000 for spaceports. (WP)
The NextGen shall forecast thunderstorms.
The NextGen shall forecast the location of thunderstorms. (WP)

The NextGen shall forecast the direction of thunderstorm movement in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast the speed of thunderstorm movement in nautical miles per hour to the nearest 5 nautical miles per hour. (WP)
The NextGen shall forecast the probability distribution function of thunderstorms.
The NextGen shall forecast thunderstorm cell intensity. (WP)
The NextGen shall forecast the thunderstorm cell locations. (WP)
The NextGen shall forecast the horizontal extent of precipitation associated with thunderstorms. (WP)
The NextGen shall forecast the accumulation of precipitation associated with thunderstorms. (WP)
The NextGen shall forecast the location of thunderstorm initiation. (WP)
The NextGen shall forecast the location of thunderstorm growth. (WP)
The NextGen shall forecast the location of thunderstorm decay. (WP)
The NextGen shall forecast the thunderstorm top in hundreds of feet. (WP)
The NextGen shall forecast total lightning.
The NextGen shall forecast horizontal extent of intra-cloud lightning. (WP)
The NextGen shall forecast vertical extent in flight levels of intra-cloud lightning. (WP)
The NextGen shall forecast horizontal extent of inter-cloud lightning. (WP)
The NextGen shall forecast vertical extent in flight levels of inter-cloud lightning. (WP)
The NextGen shall forecast the location of cloud-to-ground lightning. (WP)
The NextGen shall forecast when lightning is imminent.
The NextGen shall forecast the location of mesocyclones.
The NextGen shall forecast the direction of mesocyclone movement in degrees to the nearest 10 degrees. (WP)
The NextGen shall forecast the probability distribution function of cloud-to-ground strikes.
The NextGen shall forecast the speed of mesocyclone movement in nautical miles per hour. (WP)
The NextGen shall forecast low level wind shear at designated airports. (WP)
The NextGen shall forecast the airspeed gain and loss due to low level wind shear in nautical miles per hour. (WP)
The NextGen shall forecast microbursts at designated airports. (WP)
The NextGen shall forecast the airspeed gain and loss due to microbursts in nautical miles per hour. (WP)
The NextGen shall forecast liquid stratiform precipitation.
The NextGen shall forecast the horizontal extent of liquid stratiform precipitation. (WP)
The NextGen shall forecast the onset of liquid stratiform precipitation. (WP)
The NextGen shall forecast the duration of liquid stratiform precipitation. (WP)
The NextGen shall forecast solid stratiform precipitation.
The NextGen shall forecast the horizontal extent of solid stratiform precipitation. (WP)
The NextGen shall forecast the onset of solid stratiform precipitation. (WP)
The NextGen shall forecast the duration of solid stratiform precipitation. (WP)
The NextGen shall forecast wake vortex location at designated airports.
The NextGen shall forecast wake vortex horizontal displacement. (WP)
The NextGen shall forecast wake vortex vertical displacement. (WP)

The NextGen shall forecast wake vortex dissipation. (WP)
The NextGen shall forecast hurricanes/typhoons.
The NextGen shall forecast hurricane/typhoon category.
The NextGen shall forecast hurricane/typhoon category change.
The NextGen shall forecast hurricane/typhoon movement direction in degrees to the nearest 10 degrees.
The NextGen shall forecast hurricane/typhoon movement speed in nautical miles per hour.
The NextGen shall forecast the regions of in-flight icing. (WP)
The NextGen shall forecast the horizontal extent of in-flight icing. (WP)
The NextGen shall forecast the vertical extent of in-flight icing by flight levels. (WP)
The NextGen shall forecast the intensity of in-flight icing accumulation by aircraft type. (WP)
The NextGen shall forecast regions of super cooled liquid droplets. (WP)
The NextGen shall forecast the probability distribution function of in-flight icing.
The NextGen shall forecast the horizontal extent of super cooled liquid droplets by flight levels. (WP)
The NextGen shall forecast the vertical extent of super cooled liquid droplets by flight levels. (WP)
The NextGen shall forecast the type of in-flight icing expected.
The NextGen shall forecast approach slant range visibility for approach corridors in statute miles at designated airports. (WP)
The NextGen shall forecast weather aloft.
The NextGen shall forecast the horizontal extent of smoke aloft. (WP)
The NextGen shall forecast the vertical extent of smoke aloft. (WP)
The NextGen shall forecast the horizontal extent of dust aloft. (WP)
The NextGen shall forecast the vertical extent of dust aloft. (WP)
The NextGen shall forecast the 3-D extent of convective induced turbulence within 30 nautical miles of a thunderstorm (CIT). (WP)
The NextGen shall forecast the probability distribution function of turbulence.
The NextGen shall forecast the intensity of convective induced turbulence (CIT) in eddy dissipation rate.
The NextGen shall forecast the 3-D extent of clear air turbulence (CAT). (WP)
The NextGen shall forecast the intensity of clear air turbulence (CAT) in eddy dissipation rate.
The NextGen shall forecast the 3-D location of clear air turbulence due to topography (e.g., mountain waves). (WP)
The NextGen shall forecast clear air turbulence (CAT). (WP)

Table M-4. Draft Functional Requirements for the Function "Forecast Space Conditions

The NextGen shall forecast space conditions (e.g., solar flares, coronal mass ejections).
The NextGen shall forecast the onset of space conditions (e.g., solar flares, coronal mass ejections). (WP)
The NextGen shall forecast the duration of space conditions (e.g., solar flares, coronal mass ejections). (WP)
The NextGen shall forecast solar radiation activity affecting aviation out through 48 hours.
The NextGen shall forecast magnitude of solar radiation affecting aviation. (WP)
The NextGen shall forecast regions of high energy of solar radiation affecting aviation. (WP)
The NextGen shall forecast the regions of high energy (> 10 MeV) of solar radiation. (WP)
The NextGen shall forecast the regions of high energy (> 100 MeV) of solar radiation. (WP)
The NextGen shall forecast geomagnetic storm activity affecting aviation out through 48 hours.
The NextGen shall forecast the period of solar radiation maximum exposure out to 36 hours.
*NOTE1: Designated airport is used generically to indicate that the number of airports this requirement applies to is anywhere from the Operational Evolution Partnership (OEP) 35 to all airports. **NOTE2: WP stands for "with probability." This terminology is used to designate the weather elements that will have a probability distribution function (pdf) associated with them for use by user decision support tools. All functional requirements containing a pdf will be in the final version of this document.

Table M-5. Draft Functional Requirements for the Function "Catalog Weather Data"

The NextGen shall obtain weather measurements.
The NextGen shall obtain the location of weather measurements.
The NextGen shall obtain the date-time group for weather measurements.
The NextGen shall create weather observations.

Table M-6. Draft Functional Requirements for the Function "Analyze Weather Data"

The NextGen shall collect cataloged weather observations.
The NextGen shall perform quality control on weather observations.
The NextGen shall analyze weather observations.
The NextGen shall analyze weather forecasts.

Table M-7. Draft Functional Requirements for the Function "Run Models/ Algorithms"

The NextGen shall ingest weather observations into models.
The NextGen shall quality control weather observations.
The NextGen shall integrate ground-, space- and airborne weather observations.

The NextGen shall interpolate weather observations to model grid points.
The NextGen shall run weather models.
The NextGen shall run weather algorithms.
The NextGen shall create the weather information for the 4-D Weather SAS.
The NextGen shall write model output to file.
The NextGen shall write model output to 4-D Weather SAS.
The NextGen shall write algorithm output to file.

Table M-8. Draft Functional Requirements for the Function "Forecast Weather"

The NextGen shall forecast surface weather.
The NextGen shall forecast weather aloft.
The NextGen shall forecast other weather.
The NextGen shall update forecast as required by operational users.

Table M-9. Draft Functional Requirements for the Function "Store/Archive Weather Information"

The NextGen shall store weather information for users.
The NextGen shall store weather information into the 4-D Wx SAS.
The NextGen shall store weather information into the 4-D Wx Data Cube.
The NextGen shall store weather information for less than 48 hours.
The NextGen shall store weather information for longer than 48 hours.
The NextGen shall archive weather information for at least 15 days for accident investigation.
The NextGen shall archive weather information for at least 13 years for use in weather R&D.
The NextGen shall archive weather information forever for the production of climatology.

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Table M-10. Draft Functional Requirements for the Function "Provide Climatology"

The NextGen shall provide monthly climatologies for all users requested data.
The NextGen shall provide tropical cyclone climatology.
The NextGen shall provide 13-year weather climatology information.
The NextGen shall provide 30-year weather climatology information.
The NextGen shall provide 13-year climatology information.
The NextGen shall provide surface observation climatology information.
The NextGen shall provide 13-year climatology information.
The NextGen shall provide wind stratified conditional climatology information.
The NextGen shall provide thunderstorm climatology information.

Table M-11. Draft Functional Requirements for the Function "Display Forecasts"

The NextGen shall provide displays for meteorologists.
The NextGen shall provide weather information for user displays.